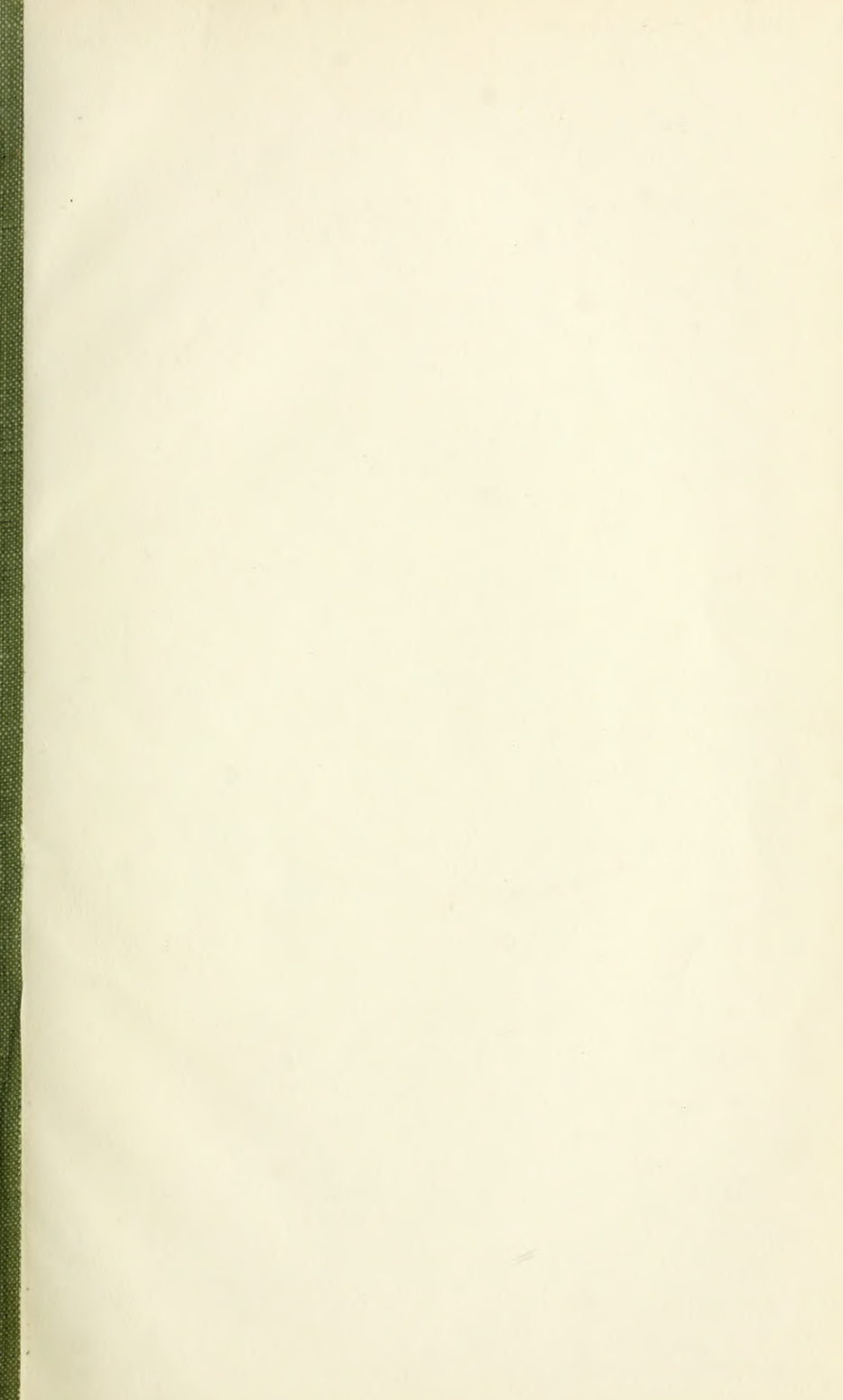

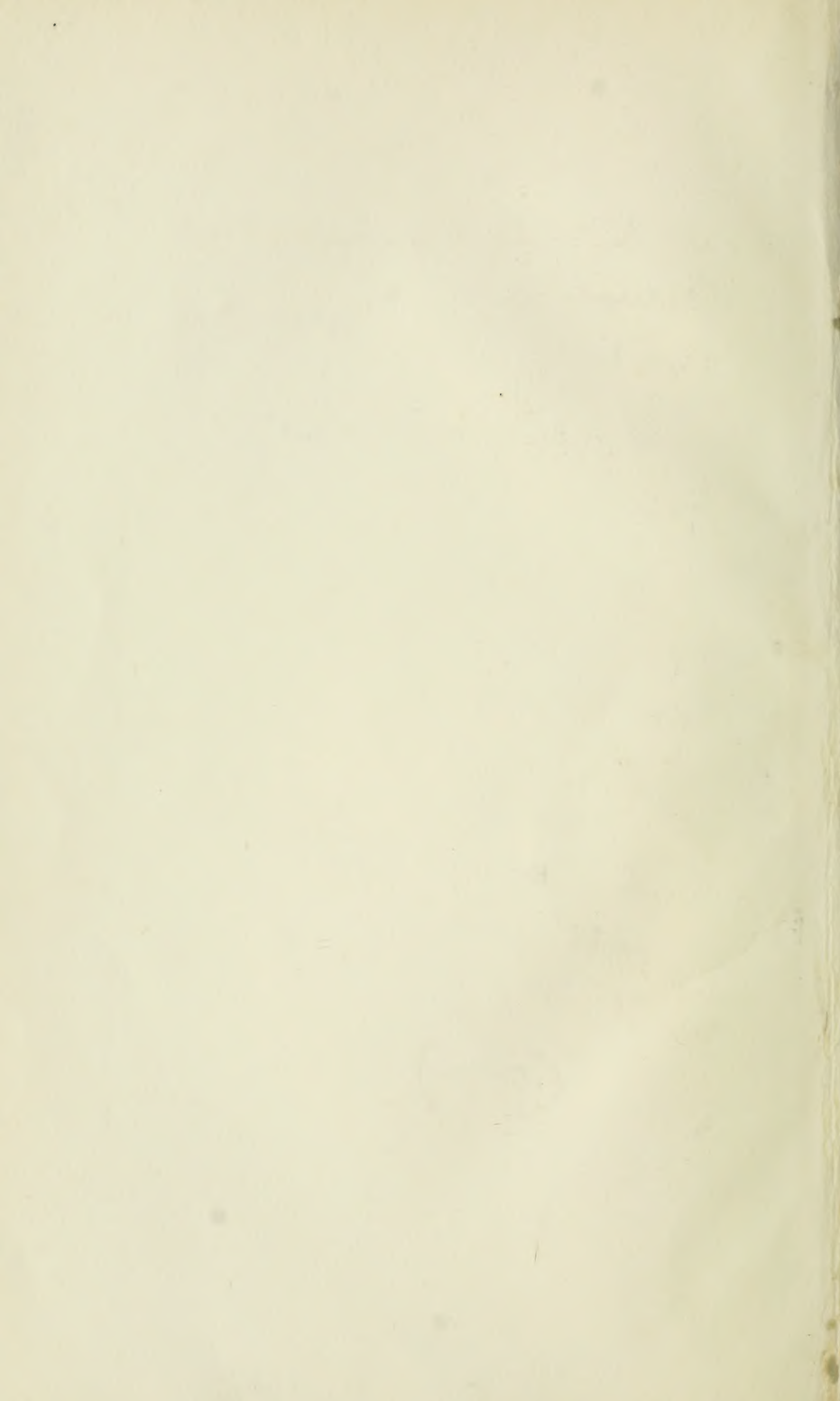


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JOURNAL
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REACTIONS BETWEEN COPPER AND CON-
CENTRATED SULPHURIC ACID.¹

BY CHAS. BASKERVILLE.

Andrews² in writing on the "Assumption of a Special Nascent State," argued that the production of sulphur dioxide, as a result of the reaction between copper and concentrated sulphuric acid, was due, not to nascent hydrogen, as is commonly considered, but to the deoxidation of sulphur trioxide by the copper with the production of copper oxide as a primary product. Having noted frequently the evolution of sulphur dioxide gas before any evidence of this "copper oxide," at the suggestion of Dr. F. P. Venable, I began some experiments with a view of studying this complicated reaction, so simply treated in most text-books.

When my work was completed, in verifying my references I chanced on Pickering's¹ work on the same subject which had escaped me. Most of my work, especially that part which concerns the secondary reactions, is in accord with that of Professor Pickering. My observations concerning the primary reactions were not

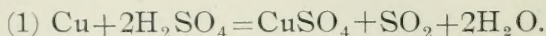
¹ Read at the Springfield meeting of American Chemical Society.

² Chem. News, 70, 152.; Iowa Acad. of Sciences, Proc. p. 4.

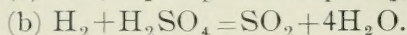
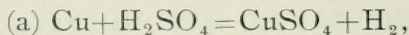
the same however. In making known the latter, I feel at liberty to give the results of my work, as independent corroboration is of some value.

The reactions which take place when copper is treated with concentrated sulphuric acid may be divided into primary and secondary.

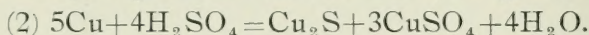
Primary:



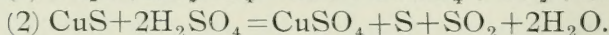
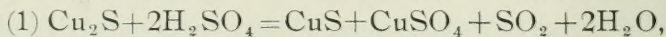
This may be regarded as taking place in two steps:



Still no hydrogen could be detected in the gas given off.



Secondary:



The experiments were carried out under various conditions of temperature and time, exposure of the metal to the action of the acid, and varying proportions of metal and acid. The copper ribbon used was cut into small pieces one cm. wide by two to three cm. long. Concentrated c. p. sulphuric acid, 1.84 sp. gr. was used. Each experiment, except where noted, was carried out in a flask in which the air had been displaced by a neutral gas, hydrogen or carbon dioxide. The evolved sulphur dioxide was led through a strong solution of sodium hydroxide and the sulphite formed titrated with a standard iodine solution or oxidized by bromine, and the sulphuric acid determined gravimetrically. A rapid stream of the inert gas was driven through the apparatus just at the close of the experi-

ment. Water was poured into the flask and the whole quickly filtered, and the copper remaining unattacked was then cleaned as well as possible by rubbing, dried and weighed. The copper, as sulphate, was determined by electrolysis. The residue was burned in a porcelain crucible, treated with concentrated nitric acid, ignited and weighed as copper oxide. Sulphur was determined by weighing a dried portion of the residue, treating with carbon disulphide, and the loss in weight taken as sulphur.

Primary Reactions. My experiments showed that the first of the primary reactions predominated when copper was treated with concentrated sulphuric acid at different temperatures (0° – 270° C.) At the highest temperature it was found that that reaction alone took place, but at all lower temperatures the second primary reaction also occurred. The proportion of the material following the second equation increased from 0° to 100° C., and then decreased to 270° C., when there was no longer evidence of any such reaction, that is, no black residue was formed.

At the lower temperatures, under 100° C., only the two primary reactions seemed to take place; at the higher temperatures the secondary reactions if the action were prolonged, frequently set in, complicating matters as far as quantitative determinations were concerned. If the time of action were shortened evidence of the occurrence of the primary reactions alone was found. Having an excess of copper present was also necessary, because as soon as all the copper had been attacked the secondary reactions set in at once.

The conditions seemed most favorable for the formation of the insoluble residue at the temperatures from 100° to 130° C. as may be seen from the table. The

proportion of the insoluble residue decreases rapidly in either direction from these temperatures. Some insoluble residue is produced at all the lower temperatures but none is produced when the reaction takes place at 270° C., and lasts for only a few seconds.

| No. | Temperature of reaction. | Copper used. | Copper as sulphate, sulphide. | | Sulphur dioxide produced. | Ratio of copper sulphate to copper sulphide. |
|-----|--------------------------|--------------|-------------------------------|--------|---------------------------|--|
| 1 | 0°-10° | 0.1350 | 0.1340 | 0.0005 | 0.1343 | 268.0 : 1 |
| 2 | " | 0.0750 | 0.0740 | 0.0003 | 0.0780 | 246.0 : 1 |
| 3 | 20°-30° | 1.3379 | 1.3260 | 0.0121 | ..... | 118.9 : 1 |
| 4 | " | 1.2473 | 1.2000 | 0.0184 | 1.2442 | 68.0 : 1 |
| 5 | 65° | 0.1650 | 0.1600 | 0.0050 | 0.1648 | 33.0 : 1 |
| 6 | 70°-80° | 0.0760 | 0.0730 | 0.0035 | ..... | 21.0 : 1 |
| 7 | 100° | 0.1380 | 0.1060 | 0.0300 | 0.0840 | 3.5 : 2 |
| 8 | " | 0.3818 | 0.2800 | 0.1082 | 0.1166 | 3.5 : 1 |
| 9 | " | 0.9200 | 0.6400 | 0.2748 | 0.2165 | 3.3 : 1 |
| 10 | 120°-130° | 5.2578 | 4.0800 | 1.1946 | 2.0932 | 3.5 : 1 |
| 11 | 140°-160° | 5.0900 | 4.5100 | 0.5759 | 3.3084 | 8.0 : 1 |
| 12 | 160°-190° | 1.1375 | 1.1200 | 0.0930 | ..... | 12.0 : 1 |
| 13 | 200°-220° | 1.5450 | 1.4518 | 0.0932 | 1.0904 | 16.0 : 1 |
| 14 | 220°-230° | 0.9815 | 0.9400 | 0.0332 | 0.9365 | 29.0 : 1 |
| 15 | 230° | 3.8915 | 3.8200 | 0.0796 | 3.6327 | 49.0 : 1 |
| 16 | 230° | 2.0000 | 1.9750 | 0.0388 | 2.2313 | 51.0 : 1 |
| 17 | 240° | 1.1235 | 1.1035 | 0.0200 | 0.9855 | 55.0 : 1 |
| 18 | 250°-260° | 2.1365 | 2.1000 | 0.0280 | 2.0304 | 80.0 : 1 |
| 19 | 270° | 4.0000 | ..... | None. | ..... | .... |

Berzelius¹ noted this black substance when copper was treated with concentrated sulphuric acid. He said it appeared to be a subsulphate because it was oxidizable by nitric acid. He made no quantitative determinations to show its composition. Such a body would contain fifty-seven per cent. of copper and in no case did I find the black residue to contain less than 67.64 per cent.

Barruel² found that sulphuric acid acted on copper at ordinary temperatures if sufficient time were given. He claimed that the sulphur dioxide produced was dissolved in the acid and attacked the copper forming cop-

¹ Traite de chimie 4, 324.

² Journ. de Pharm. 20, 13, 1834.

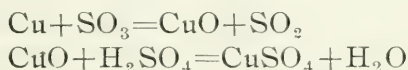
persulphide and oxide, the latter being dissolved in the acid.

Maumené¹ claimed that his black residue contained four different bodies; copper subsulphide and three oxysulphides, $\text{CuO} \cdot 2\text{Cu}_2\text{S}$ or $\text{Cu}_5\text{S}_2\text{O}$, $\text{CuO} \cdot 2\text{CuS}$ or $\text{Cu}_3\text{S}_2\text{O}$, and $\text{CuO} \cdot \text{CuS}$ or Cu_2SO .

In my analyses, as also in Pickering's, the sum of the percentages of copper and sulphur always approximated 100. In one experiment I did find a body whose composition approximated $\text{CuO} \cdot 2\text{Cu}_2\text{S}$. I shall speak of that apparent exception further on.

Calvert and Johnson² performed some experiments on the action of strong and dilute sulphuric acid on copper at temperatures from 130° to 150° C. They noted the formation of the subsulphide and claimed it was due to the liberation of free sulphur which afterwards combined with the copper direct.³ There was evidently something very wrong in their observations, for they failed to note any action below 130° C. Barriuel in 1834 had noted that action took place at the temperature of the air. I have noted the action at 0° C.

According to Andrews



are the correct formulas, SO_3 existing at the temperature necessary for the reaction, and the insoluble residue being the oxide. That would do if the reaction occurred only at those higher temperatures, whereas it occurs as well at 0° C. Besides this the undissolved residue is not the oxide at all, as he says it is, but

¹ Ann. Chim. Phys., 1846, 3rd Series, 18, 311; Traite de chimie generale, Pelouze et Fremy, 2nd Ed., I, 388.

² J. Chem. Soc., 19, 438, 1866.

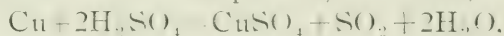
³ Pickering proved this impossible. The amount of sulphide produced was not increased by adding sulphur direct to the experiment.

invariably the sulphide. In making his analyses very likely he determined the copper alone and the percentage of copper in copper oxide and cuprous sulphide is the same. In a subsequent conversation with Dr. Andrews, I have learned that this was the case. This black residue when thoroughly washed free from any sulphuric acid always gave off hydrogen sulphide on treatment with hydrochloric acid.

The composition of the insoluble residue was determined by analysis:

| | Found. | Calculated for Cu_2S . |
|--------------|-----------------------|--|
| Sulphur..... | 20.44 | 20.14 |
| Copper..... | 79.56 (by difference) | 79.86 |
| | 100.00 | 100.00 |

In the first of the two primary reactions,



it is seen that for each atom of copper found as sulphate, one molecule of sulphur dioxide should be evolved. Calculating on this basis from the following table we have the ratio of 2 : 3 between the copper as subsulphide and the copper as sulphate unaccounted for in the production of the sulphur dioxide.

| No. | Sulphur dioxide. | Corresponding copper. | Total copper as sulphate. | Copper as sulphide. | Difference, Columns 3 and 4. | Ratio, Columns 5 and 6. |
|-----|------------------|-----------------------|---------------------------|---------------------|------------------------------|-------------------------|
| 8 | 0.1166 | 0.1158 | 0.2800 | 0.1082 | 0.1642 | 2 : 3 |
| 9 | 0.2165 | 0.2132 | 0.6400 | 0.2758 | 0.4268 | 2 : 3 |

The formula



shows that relation between the two compounds of copper.

Second Reactions.—The secondary reactions depend

1 Pickering states (loc. cit., p. 117) that once at 80°C . he observed that the copper in the two compounds stood in the relation of 2:2.9. I have not been able, however, to have concentrated sulphuric acid act on copper at any temperature from 0°C . to 270°C . without the evolution of sulphur dioxide, which is not accounted for at all in case the second of the primary reactions alone takes place, which he states did take place at 80°C .

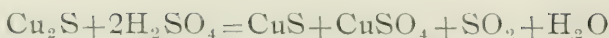
upon the second of the primary, that is, the cuprous sulphide produced. If the experiment were carried out so as to cause a rapid evolution of gas and the residue not allowed to form a protective coating over the copper, as long as an excess of the metal was present, only the primary reactions occurred. This was accomplished at 160° – 170° C. If the strips of copper were touching they almost always became bound together by the anhydrous copper sulphate and a coating of the black residue formed a protective covering to the copper. When such a state of affairs occurred, no sharply defined line could be drawn to show, of these secondary reactions, when the first ends and the second begins, because as soon as some cuprous sulphide is changed to cupric sulphide, the latter is attacked by the sulphuric acid, sulphur being one of the products of the last reaction. Several experiments carried out at 140° – 150° C. when this occurred with an excess of copper gave evidence of all the reactions, primary and secondary. Sulphur was deposited on the sides of the flask and the black residue contained 20.71 per cent. sulphur, and the theoretical percentage for cuprous sulphide is 20.138. This showed the presence of some cupric sulphide in which the percentage of sulphur is 33.59².

Some freshly prepared cuprous sulphide was treated with concentrated sulphuric acid. Sulphur was determined in the undissolved residue, the free sulphur being first removed.

| | Found. | Calculated for CuS. |
|--------------|--------|---------------------|
| Sulphur..... | 32.36 | 33.59 |

The formula,

2. Watts (vol. II, p. 41, 1875, Ed.) notes this complete decomposition.



explains such a change.

Another portion of cuprous sulphide was boiled with concentrated acid until it nearly all disappeared. The free sulphur produced was determined.

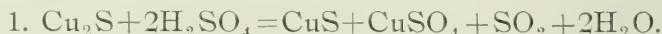
| | Found. | Calculated. |
|--------------|--------|-------------|
| Sulphur..... | 19.71 | 20.138 |

The formula



shows the final result of the continued action of sulphuric acid on the subsulphide.

From these data the secondary reactions between copper and concentrated sulphuric acid may be expressed by the two formulas,



The occurrence of sulphur on the sides of the flask at the end of the reaction may be said to be due to the sublimation of that element which is produced by the direct decomposition of sulphuric acid without the intermediate formation of hydrogen sulphide for the following reasons:

1. If hydrogen sulphide were produced by the decomposition of the sulphide, it is natural to expect some to escape in the gases which are given off. None could be detected.

2. As is well known, hydrogen sulphide is decomposed by concentrated sulphuric acid.

3. The deposit of sulphur is first noted on the sides of the flask and not in the delivery tube where the gases, hydrogen sulphide, and sulphur dioxide, would naturally come into the most intimate relations.

4. If flowers of sulphur be heated with concentrated

sulphuric acid in a flask provided with a long outlet tube, much of the sulphur will be seen to creep up the sides of the flask, and some sublimed even into the tube, which shows that the state of affairs observed may be attained without any trace of hydrogen sulphide being present.

COPPER OXYSULPHIDE.

Contradictory evidence to what has been stated above was found in one case where the insoluble residue approximated $\text{CuO} \cdot 2\text{Cu}_2\text{S}$ in composition. This is one of the oxysulphides stated by Maumené to exist in the black residue. The acid was heated to 250°C . in an Erlenmeyer flask. The air was not removed by an inert gas. The copper was suspended in long strips, only a third of which was immersed in the acid, the other part being exposed to the air.

The black residue formed under these conditions gave on analysis:

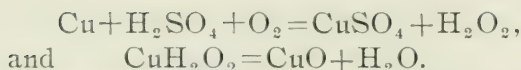
| | Found. | Calculated for $\text{CuO} \cdot 2\text{Cu}_2\text{S}$. |
|--------------|--------------|---|
| Sulphur..... | 16.16 | 16.15 |
| Oxygen..... | 3.54 | 4.03 |
| Copper..... | undetermined | 79.82 |

Schuster¹ found that copper was acted on by dilute sulphuric acid only in the presence of atmospheric oxygen. Traube² noted that copper was not oxidized in moist air, but was slowly in the presence of dilute sulphuric acid. Although copper is unable to decompose sulphuric acid at ordinary temperatures (according to Traube) its affinity for SO_4 and that of hydrogen for oxygen are together sufficient to cause such a decomposition, the probable reaction being:

1 Proc. Roy. Soc. 55, 84; Ber. d. chem. Ges., 28, 219.

2 Ber. d. chem. Ges., 18, 1887-1890.

3 Loc. cit., p. 138.



I could detect no oxygen in the gases given off when the experiments were carried out in an inert atmosphere. Nor could I detect hydrogen dioxide. Traube himself states that no "active" oxygen was liberated in the reaction because carbon monoxide was not oxidized to carbon dioxide. Pickering³ suggests that the sulphide formed is "oxidized at the time of its appearance by the oxygen which would be liberated at the surface of that portion of the copper which is immersed in the acid, since the whole arrangement would form a galvanic cell consisting of a metal, a liquid, and a gas."

UNIVERSITY OF NORTH CAROLINA.

SOME OF THE PROPERTIES OF CALCIUM CARBIDE.

BY F. P. VENABLE AND THOMAS CLARKE.

The calcium carbide used was prepared by the Wilson Aluminum Company. In this preparation, lime is mixed with some form of carbon, as coal-tar; the mass is then heated, with stirring, until a thorough mixture is obtained. The proportions are so arranged that the mass becomes dry and hard on cooling. This mass, in lumps, is then placed in the electric furnace. In a very short time after the turning on of the current, the process is complete. The molten mass can be run out of the crucible or it may be removed after cooling. On examination, it is easy to see that there is more or less carbon unchanged, or rather converted into the graph-

itic variety by the intense heat. Along with this are to be seen crystalline masses, lustrous and dark brownish black in color.

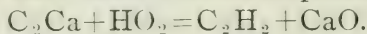
These are quite hard, and break with a crystalline fracture. Several efforts at effecting a separation from the graphitic carbon were unsuccessful. The lustre is slowly lost on exposure to air, more rapidly if the air be filled with moisture. The work will finally crumble down into a gray powder with particles of black graphite interspersed through it. The carbide can be kept for a year or two if placed in a tightly stoppered bottle and is quite easily preserved if a little coal-oil is placed in the vessel containing it.

By far the most interesting property of this carbide is its decomposition when brought in contact with water. The metallic carbides seem to be distinguished by the ease with which they exchange their carbon for the oxygen of water or for the radicals of various acids, the carbon combining with the hydrogen to form various hydrocarbons. Several authors have reported that the decomposition of this particular hydrocarbon caused the formation of acetylene. Experiments were carried out by us proving this fact, some time before there were any publications concerning it in the chemical journals, but we were not at liberty to publish anything concerning it at that time. If the gas, as evolved, is passed through a set of absorption flasks containing ammoniacal copper solution it will be entirely absorbed, not a bubble passing through, out of one or two liters of gas. Thus it seems to be pure acetylene. The amount of gas yielded by any one sample will be affected to some extent by the amount of graphitic carbon present. Hence different lots will vary some-

what. The average is about 200 cc. to the gram of carbide.

If the gas be ignited, as it is evolved, it gives a smoky flame; if it be considerably diluted, as one part of gas to from six to ten of air, a flame of great brilliancy and intensity is gotten. A company has been formed to introduce this as an illuminant upon the market. The cheapness of the materials used and the ease with which the gas can be found ought to make it a valuable and useful addition to our illuminants. If too large a proportion of air be admixed a very violent explosion can be brought about by igniting it. In some cases we have noticed the flame rapidly travelling backwards along a rubber tube towards the gasometer in which the gas was stored. One explosion taught us that care was necessary in handling the mixture.

Several analyses were attempted of the carbide, but for obvious reasons failed to give very satisfactory results. In the first place there was uncombined carbon present, also a small portion of a tarry matter, which could be detected by heating to high temperatures, and lastly, the specimens worked upon were several months old and in spite of careful keeping, had been slightly acted upon by the air and so contained uncombined lime or calcium carbonate. Moissan gives C_2Ca as the formula calculated from his analyses. This would agree well with the decomposition by water;



Action of Hydrogen upon the Carbide.—Dry hydrogen has no action upon this carbide in the cold. Several small pieces of the carbide were placed in a piece of combustion tubing, drawn out at one end to a point suitable for testing the flame. Dry hydrogen was then passed over it and as soon as the air was expelled the

hydrogen was ignited at the jet and a lamp placed under the tube so as to heat the carbide. In a little while the colorless flame became luminous and remained so a short time. A brownish, tarry matter condensed in the cooler parts of the tube. The mass of the carbide assumed a dull grey tint and a very thin white sublimate collected at a short distance from where the tube was heated. The ignition was carried on for five hours. The driving off of this tarry matter seemed to be the only action. The substance on removal from the tube, was still hard. On exposure to the air, it disintegrated, and, if thrown into the water, it was decomposed, showing the same behavior as the original carbide.

Action of Air and of Oxygen.—Some fresh pieces of the carbide were placed in the tube and heated while dry air was passed over them. A luminous flame was gotten as before and the same tarry matter was driven off and then there seemed to be no further action. Tests showed the carbide apparently unchanged at the end of prolonged heating.

Oxygen was then passed over some of the carbide which was being moderately ignited. No change was observed after two hour's heating. If the temperature was very high, such as that gotten in a combustion furnace, the carbide glowed brightly, as if burning, and a nearly white powder was obtained. The combustion was imperfect, however, unless the tube was very hot and the ignition prolonged. This refers not merely to the graphitic carbon mixed with the carbide but to the carbide itself. In several experiments the substance withdrawn from the tube, after heating some hours in oxygen, decomposed violently in water. It may be added, as was to be expected, that carbon dioxide had no appreciable action upon the carbide.

Action of Hydrochloric Acid.—Hydrochloric acid had no action upon this substance in the cold. When passed over the heated substance it caused it to swell up and assume a dirty gray appearance. A small amount of a liquid, apparently water, collected in the cooler portions of the tube and parts of the carbide fused down in glassy globules and masses. These were soluble in water and were easily shown to be calcium chloride. White fumes were evolved, some of which settled as a white solid upon the sides of the tube.

Action of Chlorine and Bromine.—When chlorine was passed over fresh carbide in the cold no action was observed. If even a moderate heat was applied, however, the lumps of carbide glowed very brightly, swelled, and fused together. A slight yellowish white sublimate was found in the tube. The fused mass was calcium carbide.

Bromine mixed with air was then passed over the fresh carbide. In the cold no action was observed. On heating, the carbide became red and the smaller pieces glowed. The lumps fused together and bubbles were observed on the surface as if some gas was escaping from the mass. Some condensed matter was found afterwards in the tube, and, on cooling, a peculiar odor was noticed different from that of the bromine. The fused mass dissolved readily in water and gave the tests for calcium bromide. Of course in this and the previous experiment the black specks of graphitic carbon were found unchanged. It was easy to distinguish them from the carbide. A few pieces of the carbide were dropped into strong, freshly prepared, chlorine water. There was a very violent disengagement of gas but it was not ignited as reported by Moissan. The gas was inflammable and burnt very much like acety-

lene. The odor was, however, peculiar. The same experiment was tried several times with a concentrated solution of bromine in water. The action again was very violent but there was no spontaneous ignition of the gas. Little difference could be detected between this and the action of the chlorine water.

Action of Acids.—A piece of the carbide was placed in concentrated pure sulphuric acid. A few small bubbles came off but the action seemed light. On heating, the action was greatly increased and continued after the removal of the flame. A gas was given off which burned with a luminous flame.

A mixture of sulphuric acid and potassium bichromate acted most violently upon the carbide. There seemed to be a very vigorous oxidation, and several attempts at igniting the gas given off resulted in failure. There could have been very little, if any, acetylene present in it.

Strong nitric acid attacked the carbide with the formation of brown-red fumes. The gas evolved could be ignited and burned with a smoky flame.

Glacial acetic acid decomposed the carbide slowly in the cold.

It may be added that no change was observed on adding a piece of the carbide to some boiling sulphur. On allowing the mass to cool the carbide was regained in its original condition.

Action of Alkalies.—A few grams of sodium hydroxide were melted in a nickel dish and a piece of the carbide was added. There was violent action, a gas being given off which burned with a luminous flame and which was taken to be acetylene.

A small amount of sodium dioxide was also melted in a nickel dish. When the carbide was added to this

it was rapidly attacked, the action being about the same as in the experiment just mentioned. An inflammable gas was evolved.

In conclusion, we would give due credit to Mr. W. R. Kenan, who carefully verified some of the experiments here recorded.

UNIVERSITY OF NORTH CAROLINA.
February, 1895.

ZIRCONIUM SULPHITE.

BY F. P. VENABLE AND CHARLES BASKERVILLE.

Very little is recorded in the text-books on chemistry with regard to this compound of zirconium. Berthier is reported as having examined it and found it to be a white insoluble body, slightly soluble, however, in an aqueous solution of sulphurous acid, from which it is thrown down again upon boiling. Whether this was what is commonly known as the neutral, or the acid, or a basic sulphite, is not recorded. It is highly probable that with so weak an acid as sulphurous acid, zirconium would form under these circumstances only basic compounds. We may state with regard to our own work that we have been unable with one exception to form any sulphite corresponding to the acid or the neutral. Only very indefinite compounds or mixtures of the sulphite with the hydroxide have come into our hands, as a rule.

The subject was first brought to our attention by the study of the reaction utilized by Baskerville for the quantitative separation of zirconium from iron and

aluminum.¹ It was also put into use by him for shortening the method of preparing the pure zirconium chlorides.² The reaction in question is that which takes place when a nearly neutral solution of zirconium chloride is boiled with sulphur dioxide in excess.

Several points of interest were observed as to this reaction. It was found that when a solution of the sulphate was used it was difficult to secure any precipitation by means of sulphur dioxide even with persistent boiling. The chloride was clearly the best salt to use. The pure chloride was made up into approximately a two and a half per cent. solution and this was either very nearly neutralized by means of ammonia, or ammonia was added until there was a slight permanent precipitate. In the latter case the saturation of this solution with sulphur dioxide produced an immediate precipitate. If this were permitted to stand for some time the precipitate was redissolved, the remaining liquid being only slightly clouded. This re-solution was probably due to the hydrochloric acid liberated and also to the excess of sulphurous acid present. If this solution of zirconium chloride saturated with sulphur dioxide were diluted with several times its volume of water and boiled from fifteen to thirty minutes, a heavy white precipitate was produced. This was quite easily filtered by means of an unglazed porcelain suction filter. The precipitate was washed several times and finally dried over sulphuric acid in a desiccator. The analysis gave:

| | | | | | | | |
|--|-------|-------|-------|------|-------|-------|-------|
| Zirconium dioxide... | 61.10 | 61.75 | 61.75 | .... | 61.00 | .... | .... |
| Sulphur dioxide..... | .... | .... | .... | .... | .... | 22.24 | 22.20 |
| Ratio of zirconium to sulphur dioxide is 2 : 1, approximately. | | | | | | | |
| Ratio of zirconium to sulphur dioxide in the neutral sulphite, | | | | | | | |
| Zr (SO ₂) ₂ , is 1 : 1.4. | | | | | | | |

1. J. Am. C. Soc. 16, 475.

2. THIS JOURNAL. 11, 85.

This substance when so dried was perfectly white and quite hard. It was powdered with some difficulty in an agate mortar and resembled, very much, finely divided silica.

It was sometimes noted that the precipitate formed on passing the sulphur dioxide into the solution of zirconium chloride was partially dissolved upon the prolonged passage of the gas. To determine in how far the liberated hydrochloric acid was the agent causing this re-solution, some zirconium hydroxide, freshly precipitated by means of ammonium hydroxide, was washed free from hydrochloric acid and was then treated with a concentrated and freshly prepared solution of sulphur dioxide. This was allowed to stand during two or three months and was frequently shaken. The solid at the bottom of the flask separated into two layers, the gelatinous hydroxide settling first and upon this a white, finely divided, substance formed. The supernatant liquid was found to contain zirconium. The white layer was separated from the hydroxide and analyzed. It contained:

| | | | |
|--------------------------|--------|-------|------|
| Zirconium dioxide | 15.05 | 15.53 | .... |
| Sulphur dioxide ..... | .... | .... | 4.86 |
| Water (blast-lamp) | 2.78 | 3.03 | .... |
| Water, at 95° C. | 77.41 | 76.33 | .... |
| | 100.10 | 99.75 | |

Ratio of zirconium to sulphur dioxide is 2.2 : 1.

This substance apparently came to a constant weight on drying in a steam-bath at 95° C.

A somewhat peculiar product was obtained during an attempt at filtering the precipitated sulphite. It filtered very slowly and in the course of a few hours a layer of a watery liquid formed above the white sulphite. This was allowed to stand several days and turned into a solid jelly. This was noticed several

times. The thickness of the jelly-like layer, would of course, depend upon the amount of moisture in the precipitate but several times it was half an inch or more in thickness. This body was analyzed in the moist condition after simply drying between filter paper. It gave:

| | | | | |
|-------------------------|--------|-------|------|------|
| Zirconium dioxide..... | 20.02 | 20.65 | .... | .... |
| Sulphur dioxide..... | .... | .... | 5.19 | 5.51 |
| Water (blast lamp)..... | 9.14 | 8.53 | .... | .... |
| Water, at 95° C..... | 65.65 | 65.22 | .... | .... |
| | <hr/> | <hr/> | | |
| | 100.00 | 99.91 | | |

Ratio of zirconium and sulphur dioxide is here 3 : 1.

A portion of this jelly was brought to constant weight by heating for a number of hours in a steam-bath. About sixty-five per cent. of the original weight was lost and the body assumed a translucent appearance like dried gelatine. The analysis of this gave:

| | | |
|--------------------------|--------|-------|
| Zirconium dioxide..... | 59.34 | .... |
| Sulphur dioxide..... | .... | 11.46 |
| Water (blast-lamp) | 29.20 | .... |
| | <hr/> | |
| | 100.00 | |

Ratio of zirconium to sulphur dioxide is 4 : 1.

The analysis shows that some of the sulphur dioxide was lost on drying.

It will be seen that these different preparations show a very varying ratio of the zirconium to the sulphur dioxide and in no case approach to the ratio of the neutral sulphite (1 : 1.4). They are, therefore, to be looked upon as either mixtures of the sulphite and hydroxide or very unstable compounds. The jelly-like substance mentioned last gives more promise of being a chemical individual; still it has not been thought legitimate to attempt the calculation or assignment of a formula to it.

A last attempt at preparing the neutral sulphite was made by placing some of the excess of sulphurous acid.

which had been standing over the precipitated zirconium sulphite, in a dessiccator and allowing it to evaporate over sulphuric acid. The bulk of liquid decreased from about 200 cc. to five to ten cc. and then hard, white, warty crystals began to form, which were quite difficult to remove from the crystallizing dish. In appearance they resembled zirconium sulphate. The solution had lost the odor of sulphur dioxide. The time consumed in the evaporation was several months.

The crystals were dried upon filter-paper and yielded, on analysis:

Zirconium 24.47 per cent. on a dry basis, 36.43.

Sulphur dioxide 34.54 " " " " 51.42.

Calculated for $\text{Zr}(\text{SO}_3)_2$, Zr 36.25; SO_2 51.20. These crystals then seemed to be a hydrated sulphite of the composition $\text{Zr}(\text{SO}_3)_2 \cdot 7\text{H}_2\text{O}$.

The nature of the precipitate gotten by means of sodium sulphite was also examined. The sulphite used was fairly pure. The zirconium chloride solution was distinctly acid and the mixed solution was acid. A transient precipitate was produced in the cold on mixing the two. On heating, a good flocculent precipitate was formed which settled well and was easily filtered. The precipitate looked like the hydroxide, rather than the white sulphite already described. The analysis gave:

Zirconium dioxide..... 5.75 5.75

Sulphur dioxide..... 1.05 1.004

Ratio of zirconium and sulphur dioxide is 4 : 1.

Chancel,¹ in giving a method of separation of iron from zirconium, states that by means of a boiling solution of sodium thiosulphite the zirconium is precipitated as thiosulphite. Stromeyer¹ stated that if a dilute

¹ Ann. d. Chem. u. Pharm., 108, 237; Watt's Dictionary, 5, 1081, 1877.

¹ Ibid., 113, 127.

zirconium chloride solution be neutralized by sodium carbonate in the cold and sodium thiosulphite added until the solution was decolorized and then boiled as long as sulphur dioxide came off, the zirconium would be precipitated as oxide meaning doubtless hydroxide.

To test these observations a solution of zirconium chloride was neutralized by ammonia and an excess of sodium thiosulphite was added in crystals. A precipitate began to be formed directly. This was washed eight or ten times by decantation, filtered, the precipitate dried by absorption paper, and analyzed. It gave:

| | | | | |
|-------------------------|--------------|--------------|------|------|
| Zirconium dioxide..... | 19.66 | 20.50 | .... | .... |
| Sulphur dioxide..... | .... | .... | 4.03 | 4.14 |
| Water (blast-lamp)..... | 16.05 | 16.41 | .... | .... |
| Water, at 95° C..... | 60.11 | 58.58 | .... | .... |
| | <u>99.85</u> | <u>99.61</u> | | |

Percentage of zirconium on a water-free basis is 75.

Percentage of zirconium calculated in $\text{Zr}(\text{S}_2\text{O}_3)_2$ is 21.95.

A second experiment was carried out with an acid solution of zirconium chloride. The sodium thiosulphite crystals were added in the cold and when completely dissolved the solution was heated to boiling. This precipitate, on analysis, gave:

| | | | | |
|-------------------------|---------------|---------------|------|------|
| Zirconium dioxide..... | 21.74 | 20.73 | .... | .... |
| Sulphur dioxide..... | .... | .... | 5.33 | 5.41 |
| Water (blast-lamp)..... | 9.72 | 8.64 | .... | .... |
| Water, at 95° C..... | 63.28 | 65.37 | .... | .... |
| | <u>100.07</u> | <u>100.15</u> | | |

Finally another portion was taken, precipitated with an excess of sodium thiosulphite, and boiled until there was no longer any odor of sulphur dioxide. This precipitate was analyzed:

| | | | | |
|-------------------------|--------------|---------------|------|------|
| Zirconium dioxide... .. | 47.01 | 47.19 | .... | .... |
| Sulphur dioxide..... | .... | .... | 6.90 | 6.95 |
| Water (blast-lamp)..... | 21.41 | 21.14 | .... | .... |
| Water, at 95° C..... | 24.16 | 24.72 | .... | .... |
| | <u>99.48</u> | <u>100.01</u> | | |

The percentage of water here was due to the exposure of the precipitate in a warm room and its consequent partial drying. There is no evidence here nor in the previous cases of the formation of any definite thio-sulphite and we would question its existence under ordinary conditions. There is no evidence of the formation here of an hydroxide as one of the authors quoted states. Basic salts seem to be the only products.

UNIVERSITY OF NORTH CAROLINA,
March, 1895.

THE CHLORIDES OF ZIRCONIUM.

BY F. P. VENABLE.

In a report upon the examination of the chlorides of zirconium¹ it was stated that pure zirconium tetrachloride was formed by the solution of zirconium hydroxide in hydrochloric acid and repeated crystallization from the concentrated acid. This statement was based on a partial analysis by Linnemann², the result of which made him call the substance the tetrachloride; and on repeated partial analyses of my own, in which the zirconium present was determined by ignition as zirconium dioxide. So firmly convinced was I of the fact that this was the normal tetrachloride that I determined to use it in revising the atomic weight. Ten closely agreedeterminations were made and they yielded as the percentage of zirconium dioxide found 52.99, or, calculating with 90.62 as atomic weight of zirconium (Bailey)

1. J. Am. Chem. Soc. 1894, 16, 460-475.

2. Lond. Chem. News, 52, 233-240.

39.16 per cent. of zirconium. The zirconium in the tetrachloride amounts to 38.99 per cent.

Bailey made several very widely differing determinations of the chlorine in this body and considered it the oxychloride. His determinations varied so greatly and his mode of drying were so faulty that I simply concluded he was mistaken, being unable to detect a source of error in my analyses which would allow for a change from 39.16 per cent. of zirconium to 46.79 per cent., the amount needed for the oxychloride.

Still, as a necessary precaution, I made some determinations of the chlorine in the pure crystalline product and was greatly surprised to find only 35.5 per cent. of chlorine instead of 61.01, the amount required for the tetrachloride. The percentage in the oxychloride would be 36.63.

I regard the results as very singular. The substance must be an oxychloride, but what is its composition? The simplicity of its preparation and the constancy of its composition, along with its stability, would argue for a simple formula. No such formula can be calculated from the analysis. Probably the best formula suggested for this oxychloride, corresponding closely with the above analysis, is $\text{Zr}_3(\text{OH})_5\text{Cl}_7 \cdot 5\text{H}_2\text{O}$.

UNIVERSITY OF NORTH CAROLINA,
August, 1895.

THE DRUDGERY OF SCIENCE.

The study of Natural Science presents so much that is attractive and entertaining that a distaste is sometimes begotten in the mind of the beginner for the sober, plodding side of it. A lecturer upon Geology

or Chemistry is at the disadvantage of having an audience which expects to be amused, as at some exhibition of jugglery, whereas the language teacher has under him those who realize fully that there is no royal road to learning. I have heard a distinguished professor of chemistry say that he always felt his class begin to drag when he passed the "fizz, pop and bang stage." They would gaze in wonder at the beautiful experiments upon the elemental gases but had no stomach for the hard work of the science. And yet, how essential this plodding, this toil without apparent, or at least immediate, reward, is to the truth of the picture and to the success of the study. The drudgery ceases to be such in the eyes of the enthusiastic searcher into nature's mysteries. It becomes a joy, as bringing him a step nearer to the realization of his hopes.

If any of you are looking forward to a life-time of work in the realms of science it is well that you should face clearly the condition demanded of you for the highest, truest success, namely, patient and often times seemingly fruitless toil. A patient worker who has just laid his tribute on the altar of science, before an admiring world of fellow-citizens—I refer to Morley and his monumental work upon the atomic weight of oxygen—writes:

"Do not deceive yourselves, however, by thinking that patient toil can accomplish everything. Genius is not 'an infinite capacity for taking pains' but a something broader and deeper, that lifts the drudgery into the sublime. You may take infinite pains and still be only a drudge. You must take infinite pains to be a brilliant leader."

One of the most valuable qualities of mind to a man of science is persistence, obstinacy, doggedness—what-

ever you may choose to call it. It means an unyielding determination to persevere in spite of difficulties and discouragements. Accuracy of observation, clearness of intellect are all good and necessary, but unless you have genuine grit, and stick at the task you have set yourself, you can make no very valuable conquest from nature nor contribution to the store of human knowledge. It is the patient settler who has cleared the land, tilled the soil, sown the seed, toiled, suffered and waited and thus has won for the world its great feeding-ground in our Western States, and so it is the patient Darwin, the toiling Agassiz, the untiring Liebig, who have opened to us such great vistas in the domain of science. If we would follow them we must toil over the stepping stones they have succeeded in laying. If we would go yet further and discover Nature's secrets for ourselves, a capacity for patient drudgery must be ours. And yet, though it seem drudgery to others who are merely looking on, it is not really such, for to us it must be a labor of love.

I wish to bring before you some eminent examples of drudges that you may draw encouragement from them. Many instances might be drawn, first, from the life of Darwin. Take, for example, his patience when he reports himself as watching for two hours to see whether a spider put the right foot or the left foot in front in weaving, and his honesty in confessing, at the end of it, that he could not tell. Consider those fifty years during which he watched the lowly earth worm and found out for us its beneficent action in preparing our soils.

Patient drudges, or shall we call them heroes, are to be found in all the branches of science. Think of Lubbock and his work with ants and bees; of Ehrenberg

and his blinding himself with his microscopic investigation of infusorial earths; of Galileo and his telescope. My acquaintance lies mostly, however, with chemists, and I shall draw from among them the examples we need.

Some years ago Dr. Kerr, our former State Geologist, supplied a distinguished English chemist, Dr. Crookes, with a large amount of a rare mineral, samarskite, found in this State. Years were spent by this gentleman in, what he speaks of as the most trying and laborious of work, fractional precipitations, in order to separate the rare elements contained in the mineral. This meant a repetition for many hundreds of times of the same delicate and trying operations. The final report of the work occupied only a few pages and gave to the uninitiated little sign of the labor spent upon it.

Another instance of the same sort of work came to my notice a few years ago. Dr. Shapleigh, an ambitious American chemist, wrote me that he too had been working on the rare earths (from cerite and monazite also gotten from this State trying to separate praseo- and neo-dymium and to prepare their compounds, with the hope of thoroughly studying them. After three years of daily toil and over 400 precipitations from 8 or 10 tons of materials, he had them separated and the compounds prepared and then found himself unable to continue the work and earn the reputation which he so richly merited.

A German chemist wishing to find out some of the constituents of the sugar-beet worked over six thousand pounds of them in small portions, by prolonged and patient operations.

We have some remarkable instances of patient toil among the older chemists also. Thus Boerhaave dis-

tilled the same lot of mercury five-hundred times to contradict the old alchemical notion that an essence could be gotten from it, and other mercury he kept at a raised temperature for fifteen years, watching for any changes, meaning countless repetitions of the same tiresome work.

I knew, myself, a young German student who, for weeks and weeks, was practically an outcast, working in a part of the laboratory to himself, unable to eat with his fellows, a burden to himself and to others because of the loathsome chemical substances he had chosen to work upon. We always threatened to put him under the sink or soak him in the water butt if he came near our part of the laboratory, and so I know little of his work or success, but he showed the scientific spirit and pluck. The work had to be done to gain the desired knowledge. It was loathsome, it was drudgery, but someone had to do it, and why not he?

I have heard of an American student who spent months in distilling and examining foetid bone oil. It seems to me, as a would-be scientific man, I should be forced to draw the line at bone-oil.

Only a year or two ago, I reported to the Society the patient toil of an English worker who was trying to understand the processes in the germination of grain. His microscopic dissections counted up into the hundreds, and yet, though spoken of casually and as a matter of course, seemed to me a marvellous proof of skill and patience.

But this drudgery may meet you at the outset of your career, and not only after you have become veterans, and if we listen to the older masters of Science, it is best for us that we should be so tried.

My teacher was one of the pupils of the great Ger-

man chemist Wöhler. He told me that when he first entered Wöhler's laboratory, the dried-up looking but brilliant German set him to grinding some hard substance in a mortar, and kept him at that and nothing else for three solid weeks. Perhaps it was the memory of this that made him set me, first, at a task of distilling water and keep me watching its drip, drip, for one long and weary week.

How such training can be of use, is told us in the charming and all too short autobiography of Justus v. Liebig, published by the German Chemical Society. His father was a dealer in colors. The boy, driven by the workings of the chemist spirit within him, experimented with his father's slender store of chemicals, and as the possible mixings and changes were necessarily limited, never wearied of repeating them, learning thus exactly the appearance and the changes they underwent, and acquiring perfected powers of observation to which he largely owed his after successes. He says, that it taught him especially to detect without fail similarities between bodies. Wöhler's training led him to take the contrary view and always to see the differences between the different kinds of matter before him. As much of their work was done in common, these two great men supplemented one another in their trained faculties, and from the farmer to the manufacturer, from the poor man who enjoys cheap clothing and better food to the suffering patient who is restored to health, mankind arises and calls them blessed.

Please note that this toil and drudgery is something different from the hap-hazard work of the alchemists and gold-seekers of the middle ages, and yet all of you have heard the tales that go to show how all-consuming was the pursuit of that flighty, illogical work.

That which I have been referring to is logical, carefully planned work, with definite ends in view.

I will close by recounting for you, in part, the story of Palissy, the potter. It may be a twice-told tale to you, but it well illustrates scientific drudgery pursued either to death or to success. Europe was without porcelain. The only pottery known to French art was common earthenware. Palissy set for himself the task of discovering how the beautiful enamel was made which could be seen on priceless ancient pieces or on imported Eastern ware.

How was he to begin? He had no teacher, he had no property. He himself says:

“Without having heard of what materials the said vessels were composed, I pounded, in those days, all the substances which I could suppose likely to make anything, and having pounded and ground them I bought a quantity of earthen pots and broke them to pieces. I put on them some of the materials that I had ground and having marked them, I set apart in writing what things I had put upon each, and having made a furnace to my fancy, I set the fragments down to bake.”

He built his furnaces, exhausted his resources and *failed*. He pulled down his furnaces, broke fresh pots, undeterred by an empty purse, an empty cupboard and a remonstrating wife, and *failed again*. Then he prepared three or four hundred pieces and sent them to a neighboring potters-kiln to be burned, after, as he says, he “had fooled away several years, with sorrows and sighs because he could not arrive at his intention.” The result was that he “received nothing but shame and loss because they turned out good for nothing.” This he did several times with failure only for his reward. Then hunger at home and the clamors of Mad-

ame Palissy could no longer be disregarded and he gave up for awhile.

For a year and a half he was conjugally a happy man, but scientifically wretched, for the fire of genius within could not be quieted. Having earned some little money by other work, he turned again to his enamel. For two years he continued his experiments and Madam Palissy scolded. His house was stripped, his children hungry. He agreed to make one final experiment, and if it failed to give up that for which he had labored five long, hard years. His trial was a partial success and nerved him to further efforts.

Time fails me to follow him through all of his trials and disappointments. I do not know of any more pitiful and yet more wonderful and stirring account of man's triumph over obstacles that most would call insurmountable.

He blundered thus for fifteen or eighteen years. He wasted away until there was no form nor prominence of muscle on arms or legs. He received no help nor consolation at home nor abroad, and yet he triumphed at last. The secret was learned, the art was won. Noblemen visited his cottage. Madame Palissy smiled again and purchased a "fine grass-green camlet" as some sort of amends for her furniture, burned in his furnace, and her years of home happiness sacrificed. He removed to court, was highly favored by the king, and France and Europe were filled with his fame.

May you have something of his energy and his perseverance and be blessed with wives more patient and more helpful than Madame Palissy.

NOTES ON THE UNDERGROUND SUPPLIES OF POTABLE WATERS IN THE SOUTH ATLANTIC PIEDMONT PLATEAU.*

BY J. A. HOLMES.

It is a fact that is coming to be more widely recognized by the general public as well as by members of the medical fraternity, that the health of persons living in our hill country depends in no small degree upon the drinking water obtained,—just as it has been found that the use of pure water in the lowlands and swamp areas of the Southern states results in practical immunity from malarial diseases. Hence the problem of how to obtain supplies of wholesome water for the towns and manufacturing establishments in the hill country or Piedmont plateau region of the south-eastern states comes to be one of considerable interest, the importance of which will continue to increase as the favorable conditions for manufactures and agriculture in this region will make it in the near future the most thickly populated portion of the South Atlantic states.

Water supplies from surface streams are unquestionably of the first importance; and in the mountain counties where the region is still largely forest covered and the streams rapid and continually aerated by rapids and cascades, the water is of superior purity and clearness. This statement is also applicable to the more elevated and sparsely settled portions of the Piedmont plateau; but in the less hilly and more thickly settled portions of this region the streams are more sluggish and the waters more muddy and less pure owing to the fact that a much larger proportion of the surface is

* From Trans. Am. Inst. Mining Engineers. XXV., 1895.

under cultivation. Furthermore, many of the towns and manufacturing establishments are located at distances from the larger rivers and creeks too great to permit of the water being lifted and transported to them by pipe lines at any reasonable cost.

Rain water caught from the roofs of houses, under favorable conditions, and kept in properly constructed cisterns, is probably the safest for drinking purposes, but under unfavorable conditions and when not properly attended to, cistern water must be considered as not altogether safe; and in any case the supply is inadequate for large establishments.

Such being the case with regard to surface supplies of water, it will be seen that, in a number of cases, we must depend for potable waters upon underground supplies. These may be obtained either from springs or wells. Of the latter we may consider three varieties: The ordinary open well such as is often seen about private residences; deep bored wells which penetrate the crystalline rocks, in the endeavor to obtain artesian supplies of water; and the shallow bored wells which are put down through the soil to the surface of these crystalline rocks in the hope of striking underground currents along the lines of contact between the lower portion of the soil and the upper portion of the undecomposed rock. In this latter case generally several such wells are bored within a short distance of each other and these are connected by iron pipes, and water is pumped from the various pipes through a common pipe to a common reservoir or tank. This is what is generally known as the tube well system.

The open springs furnish an excellent but limited supply of water for family use; a supply, however, which while it is sufficient for the needs of isolated residences,

it is generally inadequate to meet the demand about towns and manufacturing centers, and futhermore, in such latter cases, and frequently even near isolated country residences, the surface in the neighborhood of the spring becomes so contaminated with decaying organic matter that the water becomes unfit for drinking purposes. The same general statement may be made concerning ordinary open or driven wells, which for the sake of convenience must be located near residences where the surface soil becomes more liable to contamination as the region becomes more thickly settled. Examples of this are not infrequently seen, where the water from wells and springs in newly settled communities is found to be healthful, but a few years later it has become so contaminated with organic matter, which has permeated the soil from above, that sickness follows its use, and it must be finally abandoned. It is difficult, however, to get the average citizen to understand that the organic matter of the water in his well or spring comes from the soil immediately about his premises, as the prevailing notion concerning these supplies of water is that they come, not from the immediate vicinity, but from some distant region. Consequently in many of our towns and even about the isolated country residences, the barn yards and the privies and the hog pens seem to be built upon the principle of convenience alone, and this frequently places them in close proximity to the well or spring from which the family supplies of drinking water are obtained.

But outside of this the question as to the purity of the water, the supply of water from the isolated springs and open wells is generally quite inadequate for towns or manufacturing establishments of any considerable

size unless the number of these wells is greatly multiplied, and their multiplication means their wider distribution through the settlement or community, and thus a multiplication of the possible sources of disease from the drinking of contaminated waters. Nevertheless, the fact remains that, many of the towns of this region, with a population of from a few hundred to several thousand, are still without any general supply of water other than that from independant shallow wells. And while the amount of disease in such cases generally increases with the age of the town, and the physicans, at least, recognize the increasing contamination of the water as the source of this increase in sickness, yet for the lack of a better system this one continues in existence.

Deep artesian well supplies are not to be depended upon for the reason that the geologic conditions in the the Piedmont plateau region are not favorable. The rocks of this region are crystalline schists, gneiss and granites with the dips (schistosity) generally steep and varying on both sides of the vertical. A considerable number of borings varying from 100 to 1000 feet, have been made into these crystalline rocks in the Piedmont region of the two Carolinas and Georgia during the past few years, with the expectation of securing either an "artesian" (overflow) supply, or a supply that would come near enough to the surface to be reached by pumps. But the results have been generally unsatisfactory, the holes being "dry" or the supply of water being inadequate. A somewhat exceptionally favorable result was experienced in Atlanta. Some years ago (1881-82) a well was bored into the gneiss rock in the heart of Atlanta to a depth of about 2200 feet, at a cost of about \$20,000.00. At a depth of 1,100

feet a large supply of water was tapped, and it rose to within about 17 feet of the surface. For several years this well constituted the water supply for a considerable part of the city, but the water was pronounced unsafe by the medical authorities, and the well has been abandoned for a water supply from the Chattahoochee river. In a few other cases exceptionally large supplies of water have been reached; but as a rule the boring of these wells has failed of satisfactory results.

Some professional well borers, like some professional miners, with a laudable desire to be kept busy, urge that the deeper the hole the better are the chances of success; an opinion that has frequently but slight foundation in the case of the mines, and in the case of well boring it is, in this region of crystalline rocks, contrary to both theory and experience. The possibility of exceptions no one will deny, as we see that in a few of the deeper mines of this region considerable streams of water are tapped; and in some cases there is a bare possibility that the hole to be drilled for a water supply may tap such an underground stream of water, as was the case in Atlanta; but the chances are more than 10 to 1 against such "luck." As a rule these crystalline rocks become harder and more solid as we descend, the chances of securing a reasonable supply of water—never good after the hole enters the real mass of rock—may be said to decrease as the hole descends. There is, however, one certainty about this operation, and that is, other things being equal, the deeper the hole the more rapidly the cost increases.

During the past few years the tube well system mentioned above has been introduced in a number of communities in this piedmont region and with decided success in furnishing a good supply of drinking water

to the smaller towns and manufacturing communities. This system is based upon the existence of fairly well defined underground "currents" of water in regions where the topography is favorable and where the rocks have decayed to a considerable depth, and where near the lower limit of this decay there is more or less porous material through which this water may readily percolate. Of course it has been well known in the past that more or less well defined underground movements of water existed, and that at favorable locations the small currents come to the surface as springs, and that frequently, on both elevated regions and about lowlands, when wells are sunk sufficiently deep into the soil,—usually near the surface of the hard rocks,—a sufficient amount of water is found either to empty into the well as a small stream or to ooze into it from the surrounding soil and thus furnish a limited supply. But it is only recently that the location and extent of these underground sources of water have been investigated in some regions with considerable care and have been found to yield under proper treatment much larger quantities of water than have been reckoned upon in the past. This investigation has been prosecuted in this region mainly by Mr. Henry E. Knox, Jr., a hydraulic engineer, of Charlotte, N. C., and he has in this way located considerable supplies of underground water in regions where these were sorely needed.

I give below, in tabulated form, the results obtained by Mr. Knox in Piedmont North and South Carolina. His method of investigation is to examine carefully the topography and geology of the region where the water supply is needed. The topographic conditions favorable to success are, as might be expected, where there is more or less of the basin, shallow ravine, or valley,

so that the water that falls upon this surface, instead of running off in opposite directions, if the soil is sufficiently porous naturally percolates downward and tends to concentrate along the lower portion of such basin or valley where it may meet with least resistance in the more porous materials.

By way of exploring such a region, a number of holes are bored in line across the basin or valley, so as to determine the existence and location of such an underground "current" of water. In this way its position at intervals is determined and the intervening course is traced by additional borings. If the water supply is tapped by these borings it sometimes overflows; the output of the pipe at the surface of the ground and the quantity thus overflowing is measured, and pumps are then applied so that the possible yield of water can be estimated. In these underground 'streams' the water usually follows the topographic conditions, as might be expected, but in some cases it moves more or less obliquely across the ravines, showing that the overlying soil has not the same thickness everywhere, and that the topography of the soil surface is not the same as the topography of the underlying rock surface; and the water current moves along down the incline of least resistance of the rock surface, in a measure independently of the topography of the surface soil.

The fact that that the water percolates through this more or less porous material at considerable depths below the surface, of course suggests that the movement must be sluggish; but that there is a definite movement is shown by the fact that where there are a number of holes bored at intervals along the line of the "stream" and coloring matters are introduced into one of them, in a short time the color ap-

pears in the water coming from the adjacent holes in one direction but does not appear in the water from the holes in the opposite direction. But the average rate of movement has not been determined with a sufficient degree of accuracy to admit of its being stated. These currents are quite limited in their width: ranging in the cases tested, from a few feet to, in rare cases, more than 100 yards. And, as might be expected, the width is not at all constant, but while it gradually increases further down the "stream" as the supply of water becomes greater, yet this increase of width is by no means constant. The depth at which these underground water currents have been found varies from about 20 to nearly 100 feet, and generally they have been found at less than 50 feet below the surface.

The fact that in the case of some of these wells the water overflows at the surface is due to topographic rather than geologic influences. In some cases, especially at Charlotte, N. C., as mentioned in the table below, the flow from a single well amounts to as much as 10 gallons per minute. Here, as in other places where the overflow is slight—even less than one gallon per minute—the amount of water which can be pumped from such a well is considerably larger. Thus in the case mentioned at Charlotte Latta Park there are several overflowing wells with an average depth of 42 feet. The maximum natural flow from one of these wells is 10 gallons per minute, but with the application of a pump the eight wells yield readily 230,000 gallons per day. Again at Chester, S. C., one well which yields in natural overflow 6 gallons per minute, with the aid of a pump yields nearly 62 gallons per minute or 99,280 gallons per day. In another case, the maximum natural overflow of any one of the eight wells

bored at the Western Hospital, at Morganton, N. C., is only four gallons per minute, while the eight wells, with an average depth of about 39 feet, yield upon the application of a pump 165 gallons per minute or 237,600 gallons per day.

The quality of the water obtained from these wells has been pronounced satisfactory in every case by the health officials. Of course the continuation of this condition of things will depend largely upon the continued freedom from contaminating influences of these water basins, and one advantage of this system of water supply is that the basins, being generally limited in area, may be generally controlled by one or more individuals or a corporation, and may be thus kept free from sources of contamination.

As might be expected, the search for the underground supplies of water has not by any means been successful in every case, but the limited experience leads one to believe that they may be found in a majority of communities, where search is extended over a sufficiently large area and is made with sufficient care. It would at present, however, be too much to claim that these underground supplies of drinking water can be found sufficient to meet all the demands of larger towns and cities, though they would prove of material service in this connection. But I anticipate that they will be found of greatest importance in connection with water supplies of smaller towns and of more or less isolated manufacturing establishments, where there are usually several hundred or several thousand operatives.

In the following tabular statement will be found a list of the more important places where these underground water currents have been found and where the gang well system has been introduced, the name of the

special establishments for which the wells were bored, the number of wells at each place, the average depth of the wells, the natural overflow in one minute of time from that one of the series of wells from which the overflow is largest, and the aggregate yield of water from the several wells at each place in 24 hours when the steam pump is applied. The data for this tabular statement has been supplied by Mr. Henry E. Knox Jr., of Charlotte, N. C., who bored all of these wells, and who states that out of 23 surveys made by him, only three were unsuccessful in locating the desired quantity and quality of water.

LIST OF FLOWING WELLS IN THE PIEDMONT PLATEAU REGION OF NORTH AND SOUTH CAROLINA.

BORED BY HENRY E. KNOX, JR., HYDRAULIC ENGINEER, CHARLOTTE, N. C.

| PLACE. | Average Depth in feet. | Strata. | No. of wells. | Max. flow per minute from one well. | Pumping capacity 24 hours. | For whom bored |
|-------------------|------------------------------|----------------|---------------------|---|----------------------------------|-----------------------------|
| Burlington, N. C. | 27.5 | Bed of gravel. | 5 | 1 Gallon. | 20,000 Gals. | Aurora Cotton Mills. |
| Morganton, " | 28.3 | Decom. gneiss | 8 | 1 " | 150,000 " | Burke Tanning Co. |
| " | 39.0 | " " | 8 | 4 " | 237,600 " | State Hospital. |
| " | 41.0 | " " | 5 | 1 " | 100,000 " | Deaf and Dumb School. |
| Rock Hill, S. C. | 56.0 | " granite | 4 | 5 " | 72,000 " | Winthrop N. and I. College. |
| Fort Mill, " | 35.0 | " " | 4 | 5 " | 30,000 " | Fort Mill Man'f. Co. |
| Pelzer, " | 21.0 | " gneiss | 4 | 10 " | 100,000 " | Pelzer " |
| " | 38.0 | " " | 5 | 1 " | 100,000 " | " " |
| Chester, " | 40.3 | " granite | 1 | 6 " | 99,280 " | Gingham Mills. |
| " | 42.5 | " " | 1 | 2 " | 30,000 " | " " |
| " | 72.0 | " " | 2 | 1 " | 30,000 " | Catawba " |
| Charlotte, N. C. | 42.0 | " " | 10 | 10 " | 230,000 " | E. D. Latta. |
| " | 51.5 | " " | 10 | 2 1/2 " | 200,000 " | Water Works Co. |
| Jonesboro, " | 31.0 | " schist | 1 | 1 1/2 " | 5,000 " | Jonesboro Cotton Mills. |
| Reidsville, " | 28.0 | " granite | 10 | 1 " | 100,000 " | Edna Cotton Mills. |



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NOTES ON THE KAOLIN- AND CLAY--
DEPOSITS OF NORTH CAROLINA.*

BY J. A. HOLMES, CHAPEL HILL, N. C.

As the Appalachian mountains reach their maximum development in western North Carolina, we find also in that region indications of extensive dynamic disturbances and alterations undergone by the rocks in connection with these mountain uplifts. Among the minor results of these changes have been the formation of numerous dikes of "veins" of exceedingly coarse granitic materials, which in some places are mined for the mica which they contain, and in other places are quarried for kaolin. These dikes are filled with quartz, feldspar and mica, in varying proportions, very coarsely crystalized. Sometimes the mica (generally muscovite), sometimes the feldspar (generally albite or orthoclase), predominates. When the mica is present in considerable quantity and in large crystals, the dyke is usually spoken of as a mica-vein, and is often worked for mica. Sometimes these crystals of mica occur on one side or the other, sometimes on both sides,

* From the Transactions of the Am. Inst. of Mining Engineers, Vol. XXIV, 1895.

and sometimes they are largely concentrated in the middle of the vein, or, it may be, distributed throughout the dike with a considerable degree of uniformity. In many cases the crystals are too small and few to permit of the working of the vein as a mica mine; in other cases very little mica is present, and the feldspar constitutes the larger part of the material. This feldspar of the dikes undergoes, through the weathering action of the atmosphere, certain chemical changes resulting in its alteration from feldspar into kaolinite—the kaolin of commerce.

These dikes vary considerably in size, ranging from a few inches to several hundred feet in thickness, and up to many hundred yards in length. They are generally parallel to the schistosity of the crystalline rocks, which, however, in some cases, they cross at various angles.

The kaolin in those dikes which occur in the Unaka or Smoky mountains is said to have been mined by the Indians, "packed" across the country to the seaboard, and shipped to England as early as the 17th century. From one of them, near Webster in Jackson County, kaolin is now mined (by the Harris Clay Co.) and shipped to Trenton, N. J. and other centers for the manufacture of fine pottery. This Webster dike contains very little mica and comparatively little quartz. It has a maximum width of about 300 feet, and has been traced for a length of more than a half mile. It is mined to a depth of from 60 to 120 feet, below which the original feldspar has not been sufficiently altered, and is too hard for economic mining. The kaolin is brought from the mine, crushed, and washed in a series of settling-vats, for the purpose of separating it from the granular quartz. Its plasticity is increased

both by washing and by the subsequent grinding which it receives. The following analysis* of the washed and dried product ready for shipment shows the general character of such material.

ANALYSIS OF KAOLIN, HARRIS MINE, NEAR WEBSTER, N. C.

| | PER CENT. |
|--|-----------|
| Free silica, silicic acid and sand | 2.28 |
| Combined silica | 41.62 |
| Alumina | 40.66 |
| Oxide of iron | 0.14 |
| Alkalies | 0.46 |
| Lime | none |
| Magnesia | trace |
| Combined water | 14.00 |
| Moisture | 0.84 |
| Titanic acid | none |
| Total | 100.00 |

Many similar but smaller feldspathic and kaolin dikes are found in the various other counties west of the Blue Ridge, and at a number of these the feldspar has been altered into kaolin for considerable depths below the surface, but none of them have been worked extensively for either the feldspar or the kaolin, except the Harris clay-mine just mentioned. Also at various points in the Piedmont Plateau, which extends east of the Blue Ridge for from 150 to 200 miles, there are to be found deposits of this kaolin which have doubtless originated in much the same way as those west of the Blue Ridge; but none of these are now worked to any considerable extent. The age of these crystalline rocks in the Piedmont plateau and the mountain

* Made for the Harris Clay Co. of Dillsboro, N. C. at the Pittsburgh Pa. Testing Laboratory.

counties, and the exact time at which the disturbance took place which resulted in the formation of these massive granitic dikes is, as yet, a matter of doubt.

So numerous are these dikes in certain places, and so long have their feldspars been undergoing surface transformation into residual kaolin or clay, that one might expect to find in this region, as in some other countries, sedimentary deposits of this material which had been transported for greater or less distances; but when we bear in mind the general elevation in the mountain-region and the consequent rapidity of its streams, we can readily understand that this product of denudation would scarcely be deposited until it had been carried so great a distance from the original source as to be lost by commingling in the lowlands with larger proportions of other and different materials.

Along the borders of the Piedmont plateau-region there are occasionally found deposits of this kaolin material which has evidently been carried but a short distance. Such occurrences are more extensively known on the western border of the Coastal Plain region, mainly in the Potomac formation, as in the neighborhood of Aiken, S. C., and Augusta, Ga., and in many other places, where considerable deposits of this kaolin-material occur, both in the form of arkose (where the kaolin is still mixed with the quartz and mica of the original granitic formation) and in the clay-beds, where it has been more completely sorted, and the kaolin has been separated from the coarser materials, so as to form extensive beds of what is locally termed "china"-or potters-clay. In some cases, in the arkose material just referred to, the partially decayed crystals of feldspar are frequently found with the kaolinization incomplete; and mingled with these are fragments of

other minerals, transported from the debris of the crystalline rocks occurring along the borders of the Piedmont plateau, not many miles away.

The points above noted may explain, perhaps, the confusion which has arisen in the use of the term "kaolin." The applicability of this name to the material described above as having its origin directly in the large granitic dikes, I suppose no one will question. But if the residual material of dike-decomposition has been transported a short distance by the streams and deposited without further sorting the materials, or if it has been transported to a much greater distance, so that the sorting has become fairly complete, and the mineral kaolinite, while separated from the quartz and mica of the original mass remains unmixed with other foreign materials, so as to be itself fairly pure,—the question arises whether the term kaolin is still applicable in both cases; and if so, to what extent, in its transportation and sorting, this material may become mixed with other foreign materials resulting from the decay of crystalline rocks in the region through which it has been transported, before the term kaolin would become inapplicable. In other words, where, in such a case, should we discontinue the use of the word "kaolin" and apply the broader term "clay"? Further discussion of this question cannot be attempted in this paper; but it is mentioned here because the writer has recently heard a number of complaints from practical potters who use the clay-material on a commercial scale, that many people throughout the country were designating all the samples of their material forwarded as "kaolin," regardless of their color and other characteristics.

Through many places, both in the mountain- and the

Piedmont plateau-regions, there are deposits of clay resulting from the decay of granites, gneisses and crystalline schists. Many of these have a structure which would indicate that the materials have been transported for greater or less distances. But in, perhaps, many other cases, the materials have evidently decayed in place, since the gradations can be traced from the clay down into the partly altered rock below. These clays, of course, vary in composition with the character of the rocks from which they have been formed. They have frequently a reddish or yellowish color, due to the oxides of iron present, though in many places the colors are much lighter, the iron having been removed through the action of organic matter. As will be seen from the above statement, these may be classed as partly residual clays and partly transported clays. They have been worked on a small scale in many places for brick; and in a few places, as at Biltmore (Buncombe County and at Pomona (Guilford County) they have been used in the manufacture of tile-, drain-, and sewer-pipes; also at Pomona for fire-brick; and near Grover (Gaston County) for fire-brick and vitrified or paving-brick.

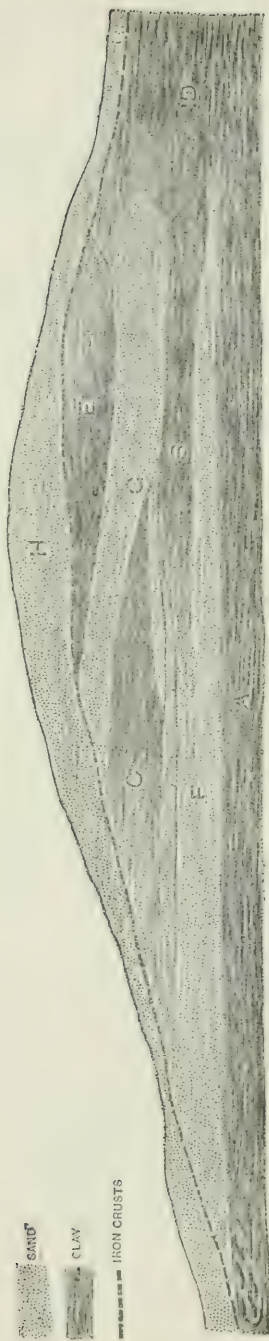
The age of these transported clays of the mountain- and Piedmont plateau-counties is unknown. Some of them, upon careful investigation, may be shown to belong to certain definite recent geologic periods; but most of them, probably, cannot be ascribed to any definite geologic time, but must be attributed simply to local conditions; and their age is probably recent. The clay and brick-loam deposits along the river terraces of the mountain and Piedmont counties which, in many places, are well adapted to the manufacture of brick, may be Columbian or older in age.

Those residual clays of these regions which have been formed *in situ* are the result of the processes of decay, the operation of which cannot be limited to any definite epoch, but may be ascribed, in general, to recent geologic time.

The most extensive beds of clay known in North Carolina are those found in the Coastal Plain region. In the Potomac lower Cretaceous formation, there are extensive beds of laminated, dark-colored clays, exposed along the banks of rivers crossing the coastal-plain region, notably on the Cape Fear river, for fifty miles below Fayetteville. These clays are usually dark in color, owing to the vegetable matter which they contain; and, in some cases, they are highly lignitic. The thin laminae are frequently separated by still thinner partings of sand; and frequently within a short distance (from a few feet to a few hundred feet) the clay-laminae become thin and disappear, while the sand-partings gradually thicken, so that the whole assumes the character of a sand-bed instead of a clay-bed. This feature, which indicates plainly the shifting conditions under which these deposits were laid down in certain localities, illustrated in the accompanying sketch of the river bluff at Prospect Hall on the Cape Fear river, 21½ miles below Fayetteville.

In some portions of these clay-beds, pyrite occurs in such quantities as would probably interfere with their industrial use; but the larger portion of the deposits appears to be free from pyrite, and will probably prove to possess considerable economic value. Thus far no efforts have been made to utilize them; but both analytic and practical tests of them are being made at the present time.

Along the western border of the Coastal Plain re-



Clay beds in Prospect Hall Bluff, Cape Fear River.

A, clay 10 feet thick above medium-low water; B, clay 6 to 8 feet thick; C, clay 12 to 15 feet thick; D, clay 40 feet thick; E, clay 15 feet thick; F, laminated sand with thin clay partings; G, sand with thin clay partings, 12 feet thick; H, laminated yellowish and whitish sand with thin loam partings, 15 to 18 feet thick, becoming loose, nearly pure whitish sand near the surface. [Except the left end down stream the iron crusts are much more prominent there than is indicated in the drawing.

gion, especially in Moore and Harnett Counties, there are limited exposures of silicious Eocene deposits (overlying the Potomac series, and capping some of the sand-hills) which have recently been tested for fire-brick with very satisfactory results. These deposits are from 5 to 15 or more feet in thickness, and are overlaid by but a few feet of loose sand. The following analysis of this material, collected two miles N. E. of Spout Springs,* shows its general composition.

ANALYSIS OF "FIRE-CLAY" (EOCENE) TWO MILES N. E. OF SPOUT
SPRINGS, N. C.

| | |
|--------------------------|-------|
| Silica | 87.70 |
| Alumina | 3.29 |
| Ferric oxide | 2.81 |
| Lime | 0.48 |
| Magnesia | 0.40 |
| Alkaline chlorides | 1.48 |
| Loss on ignition | 3.15 |
| Total | 99.31 |

Among the Miocene deposits, there are, in places along the river-bluffs of the Coastal Plain region, especially on the Roanoke and the Tar, somewhat extensive exposures of "blue marl," a calcareous clay which may prove to be of some value, but of which no practical tests have yet been made-

The Lafayette (Pliocene) materials, which are spread over so large a portion of the Coastal Plain region, are generally gravelly or sandy in composition, with a large admixture of loam in many places. No extensive deposits of clay have been observed among the materials of this formation, though doubtless limited deposits of clay will be discovered as more extensive explorations are made.

* Made in the laboratory of the N. C. Geological Survey.

The later deposits bordering the river-courses and covering the river-terraces, at elevations from 20 to 100 feet above sea-level, which may be designated as the river phase of the Columbian formation, contain extensive beds of sandy clays and brick-loams; and, throughout the entire Coastal Plain region of the South Atlantic States, it is these deposits which are most largely used in the manufacture of brick.

A DESCRIPTION OF SOME OF THE MUSCLES OF THE CAT.

BY H. V. WILSON AND G. H. KIRBY.

The most complete account extant of the cat's muscular system is that found in Strauss-Durckheim's *Anatomie du Chat*¹. The expense of the work, however, renders it inaccessible to many. And in spite of the great beauty and general accuracy of the plates, it is not well adapted to the purposes of the dissector, owing chiefly to the length and detailed character of the descriptions (e. g. *psoas-muscles* and *quadratus lumborum*) and in a less degree to what we regard as the misleading subdivision of the muscles of certain groups (e. g. *pectoral* group). With due deference to such a magnificent work, the results of dissection lead us to differ from Strauss-Durckheim in certain points of detail, to some of which attention is called.

Perhaps the most generally useful work on the cat is that of Mivart². The descriptions and accompanying

¹ Strauss-Durckheim. *Anatomie Descriptive et Comparative du Chat*. 2 vols. and Atlas. Paris, 1845.

² St. George Mivart. *The Cat*. New York, 1895 (latest issue).

figures enable the dissector to identify without trouble most of the muscles. But this part of the work, at least, contains too many inaccuracies to make it a safe guide. In like manner the value of a recently published hand-book³ is much impaired by inaccurate statements regarding the origin and insertion of many of the muscles described.

Finally, that most original and valuable work, the "Anatomical Technology," only includes a description of the muscles of the chest, shoulder and fore-leg. The accurate nature of all the descriptions in the "Technology" has long been recognized, and the few points in which our description of the pectoral muscles differs from that of Wilder and Gage⁴, are doubtless varying points. In spite, however, of its accuracy, the account given in the "Technology" of the cat pectorals seems to us an unnecessarily difficult one to follow. This is in part due to the manner in which the group is subdivided.

ABDOMINAL MUSCLES.

External oblique. This muscle arises along its external border from the nine last ribs and from the lumbar fascia. The attachments to the ribs interdigitate with the slips of the *serratus magnus*, and lie beneath the *latissimus dorsi*. The lumbar fascia from which the muscle arises is the superficial fascia which may be peeled from the underlying *transversalis abdominis*, and may be traced to the spinous processes of the vertebrae.

Along its inner border the muscle passes into a broad,

³ Gorham and Tower. A Laboratory Guide for the Dissection of the Cat. New York, 1895.

⁴ Wilder and Gage. Anatomical Technology as applied to the Domestic Cat: New York and Chicago, 1882.

thin aponeurosis, which is closely bound to the subjacent *rectus abdominis*, and unites with its fellow of the opposite side along the *linea alba*. This aponeurosis extends from the *symphysis pubis*, to which it is attached, forwards to the level of the ninth costal cartilage. The anterior part of the aponeurosis underlies is dorsal to, the most posterior *pectoral* muscle. The posterior and external edge of the aponeurosis, extending from the *symphysis pubis* obliquely dorsally and posteriorly, is known as *Poupart's ligament*. Near the symphysis the aponeurosis is perforated by an aperture, the *external abdominal ring*, which is the external opening of the *inguinal canal*. This aperture lies between *Poupart's ligament* and the rest of the aponeurosis.

Synonymy. *Oblique-interne abdominal*, S. D., vol. II, p. 314; *external oblique*, M., p. 141; *external oblique*, G. & T., p. 28.

Mivart is wrong in stating that the muscle arises from the *eight* last ribs; and that Poupart's ligament extends from the symphysis pubis to the *Ilium*. The latter statement is true of human anatomy; but in the cat the ligament (or free edge of the aponeurosis) passes in front of the ilium, having no connection with it. Gorham and Tower commit the same mistakes.

The account given of the muscle both by Mivart and Gorham and Tower would indicate that Poupart's ligament is something distinct from the tendon or aponeurosis of the *external oblique*. Mivart in this matter, is not intelligible. He states that the aponeurosis divides into external and internal tendons, between which lies the "external abdominal ring," bounded in front by Poupart's ligament. Possibly the "in front" is a misprint, for the ligament lies *behind* the abdominal ring.

Internal oblique. The muscle arises along its external border from the superficial lumbar fascia, directly beneath the origin of the *external oblique*; and from the ventral margin of the ilium. At its posterior end the muscle arises from the pubis.

The fibres run anteriorly and ventrally. At some distance external to the *rectus abdominis*, they pass into a thin aponeurosis, which throughout its anterior extent is firmly attached to the underlying (*i. e.* dorsal) *transversalis abdominis*, and is thus dorsal to the *rectus abdominis*. Throughout its posterior extent the aponeurosis extends ventrally over the *rectus abdominis*, being indistinguishably united with the aponeurosis of the *external oblique*.

At its anterior end, near the dorsal border, the muscle is attached directly by its fibres to the last rib. The muscle may here be seen to be a continuation of the layer formed by the *internal intercostals*. The *internal intercostal* between the 12th and 13th ribs, is in fact *directly* continuous with the *internal oblique*.

Synonymy. *Oblique-interne abdominal*, S.-D., vol. II, p. 315; *internal oblique*, M., p. 142; *internal oblique*, G. & T., p. 29.

Mivart is wrong in stating the muscle to be "inserted inside the cartilages of the last ribs." Gorham and Tower inexactly state "the more anterior fibres to be inserted on the cartilages of the *ribs*." According to Strauss-Durekheim the relations of the aponeurosis of the *internal oblique* to the *rectus* are quite the same as in human anatomy, in that anteriorly the aponeurosis splits into two layers which ensheath the *rectus* dorsally and ventrally. This ventral limb of the anterior part of *rectus* sheath, if it ever is present, must con-

sist of a very few and delicate fibres. It was not observed in any of the several cats dissected by us.

Transversalis abdominis. The muscle arises along its dorsal border, just beneath the *erectores spinæ*, from the fascia covering the ventral surface of the latter (middle layer of the lumbar fascia in human anatomy). It also arises from the cartilages of the false ribs and from the ventral margin of the ilium.

Along its inner border it is anteriorly, and for the greater part of its course, inserted into a broad, thin aponeurosis which lies dorsal to the *rectus abdominis*, and is continuous with its fellow of the opposite side as an independent aponeurosis. Posteriorly, however, the fibres of the muscle pass into a fascia, lying ventral to the *rectus abdominis*, and inseparably united with the combined aponeuroses of the *external* and *internal oblique*.

Synonymy. *Latitudinal*, S.-D., vol. II, p. 317; *transversalis*, M., p. 142; *transversalis abdominis*, G. & T., p. 29.

According to Mivart the muscle ends in an aponeurosis lying dorsal to the *rectus*. Gorham and Tower give the muscle as ending "in an aponeurosis beneath the rectus." Both authors thus overlook the important difference in position between the anterior and posterior portions of the aponeurosis. Strauss-Durckheim evidently recognizes this difference, though he does not explicitly state it. He designates the aponeurosis as the third layer of the abdominal aponeurosis, and goes on to say: "Ce feuillet—s'unit á celui de l'oblique interne, et se comporte du reste comme lui."

Rectus abdominis. The muscle arises from the symphysis pubis. It is completely separated by the connective tissue of the *linea alba* from its fellow of the

opposite side; and is inserted on the first, second and third ribs, the chief insertion being on the first.

At about the level of the ensiform cartilage, the muscle gives off a small slip, which is inserted along with its fellow of the opposite side, into the aponeuroses of the *external obliques*, in the median line, beneath the posterior (fifth) *pectorals*.

The *rectus abdominis* is ensheathed in the aponeuroses of the two *obliques* and the *transversalis*. Posteriorly all these aponeuroses lie ventral to it. Anteriorly the aponeurosis of the *external oblique* is ventral, but the aponeuroses of the *internal oblique* and *transversalis* are dorsal to it.

Synonymy. *Droit-abdominal*, S.-D., vol. II, p. 307; *rectus abdominis*, M., p. 142; *rectus abdominis*, G. & T., p. 29.

The slip given off in region of ensiform cartilage, is not mentioned by the writers cited above. It probably corresponds to the fibres said to be attached to the ensiform cartilage in human anatomy.*

* Quain's Anatomy, 10 ed., vol. II, pt. 2, p. 334.

Our account of the rectus sheath differs from that of Strauss-Durckheim, in that we do not find the aponeurosis of the *internal oblique* dividing into ventral and dorsal limbs which embrace the *rectus* anteriorly, as already mentioned in connection with the *internal oblique*. Mivart, and Gorham and Tower, overlook the insertion of the posterior part of the *transversalis*, and thus give an imperfect account of the sheath.

PECTORAL MUSCLES.

The pectoral muscles form a triangular mass on the front of the chest, running from the median line of the body to the arm. The mass is divisible into five dis-

inct muscles. These may be arranged in two groups. One group includes the first, second, and third *pectorals*, all of which muscles arise from the anterior portion of the sternum and run outwards. This group corresponds in a general way with the more superficial (*P. major*) of the two *pectorals* of man. The other group includes the fourth and fifth *pectorals*, which muscles in general pursue a course from the sternum outwards and *anteriorly* to the proximal end of the humerus. This group corresponds with the inner human *pectoral* (*P. minor*). In a general way it may be said that the muscles of one group cross those of the other. (On this crossing of the *pectoral* muscles, see Wilder and Gage, p. 235).

The first *pectoral* is the most superficial of the group. It is rather narrow and band-shaped, and arises from the presternum and the raphé in front of the latter. The raphé in question is the median connective tissue septum between the posterior portions of the *sternomastoids*, and between the anterior portions of the second *pectorals*. The greater part of the muscle arises from the mid-ventral line of the presternum, along the anterior three fourths of that bone. Only the extreme anterior part arises from the raphé.

Part of the muscle is inserted along with a shoulder muscle, the *cephalo-humeral*. Part is inserted into the fascia of the fore-arm, along with a slip from the third *pectoral*.

Synonymy. *Pecto-antebrachial*, S.-D., vol. II, p. 352 (the slip from the third *pectoral* is regarded as the "second chef" of the *pectoantebrachial*); *pecto-antebrachial*, W. & G., p. 236 (above-mentioned slip is counted as the "caudal division of the *pecto-antebra-*

chial"); *pectoralis, part I.*, M., p. 145; *pectoralis, part a*, G. & T., p. 30.

There is no actual union, in cases at least, between the muscular part of the distal end of the slip from the *third pectoral* and the *epitrochlear*, as W. & G. state (p. 238). The slip is in close juxtaposition to the *epitrochlear* along its posterior border.

The origin of the muscle, as given by Mivart, is inaccurate: "from beneath the manubrium and attachment of the first two costal cartilages." Gorham and Tower give the same origin as Mivart.

The *second pectoral* is a wider muscle than the first. It is superficial just in front and just behind the first, but the greater part of it is covered by the latter. It arises from the presternum and the median raphé, above referred to. The muscle arises from the mid-ventral line of the presternum along the entire length of the latter. The anterior portion arising from the raphé is noticeably thicker than the rest of the muscle.

The chief insertion is on the outer surface of the humerus, along the middle third of that bone, external to the attachment of the *third pectoral*. The fibres lying along the posterior border of the muscle are inserted into the bicipital arch.

Synonymy. *Premier chef du large pectoral*, S.-D., vol. II, p. 343; *lamina ectalis of the ectopectoralis*, W. & G., p. 238; *pectoralis, part 5* (partially), M., p. 147; *pectoralis, part e* (partially), G. & T., p. 31.

Mivart's *part 5* apparently only corresponds to the anterior portion of our *second pectoral*. M. is inaccurate regarding the origin, which he says is from the manubrium: "The *fifth* * * is the most anterior. It arises from the manubrium." The origin from the median

raphé is thus overlooked. Gorham & Tower agree with Mivart.

The third pectoral is a wide muscle. Anteriorly it is covered by the *first* and *second pectorals*, but the posterior half or more is superficial. It arises from the above-mentioned raphé, from the presternum, and from the next two sternebrae, its origin thus extending as far back as the attachment of the fourth costal cartilage to the sternum. Only the extreme anterior portion of the muscle arises from the raphé. Behind these fibres, the muscle arises from the ventro-lateral surface of the presternum, along the whole length of the latter. The portion of the muscle arising from the next two divisions (sternebrae) of the sternum is superficial.

The chief insertion is on the humerus, and is a very long one. The proximal part of this insertion is by a thin aponeurosis to the extreme outer surface of the humerus. The middle part is directly by muscle fibres to the ventral surface of the humerus. The distal part is again by aponeurosis to the ventral surface of the humerus.

The most anterior fibres of the muscle are inserted into a small tendon which quickly divides. One division passes externally to the shoulder joint, and is attached to the outer end of the clavicle. The other division passes internally to the shoulder-joint, and terminates in the fascia on the mesal surface of the scapula in the interval between the *supra-spinatus* and the *sub-scapularis*.

The muscle is also inserted into the bicipital arch. As has already been mentioned, a slip lying along the posterior border of this muscle separates from it, and is inserted along with the *first pectoral*.

Synonymy. *Second chef du large pectoral*, S.-D.,

vol. II, p. 343; *lamina entalis of the ectopectoralis*, W. & G., pp. 239-240; *pectoralis, part 2* (partially), M., p. 145; *pectoralis, part b* (partially), G. & T., p. 30.

Wilder and Gage divide the muscle into two subdivisions, cephalic and caudal. This division seems to us an arbitrary one. We do not find the muscle naturally so divided. Mivart's *part 2* apparently includes our *third pectoral* and the posterior part of our *second pectoral*.

The *fourth pectoral* is a wide, thick mass, being much the largest muscle of the group. At its origin it is a single, undivided muscle, though distally it splits into two subdivisions, anterior and posterior, having different insertions.

The muscle arises from nearly the whole sternum. The origin begins just posterior to the presternum, and includes all the mesosternebrae and the anterior two-thirds of the xiphi-sternum.

Of the two subdivisions into which the muscle splits distally, the anterior is inserted on the great tuberosity of the humerus, coming here into close connection with the *supra-spinatus*. The insertion of the posterior subdivision is complex. The chief part is inserted on the proximal half of the ventral surface of the shaft of the humerus, anteriorly by muscle fibres, posteriorly by aponeurosis. The fibres forming the posterior portion of this subdivision are inserted, along with the *latissimus dorsi*, into the bicipital arch. Into the posterior border of this subdivision run fibres belonging to the great cutaneous muscle, the *panniculus carnosus*.

Synonymy. *Sterno-trochiterien plus premier chef du grand pectoral*, S.-D., p. 337, p. 341; *ento-pectoralis*, W. & G., p. 241, *pectoralis, part 3*, M. p. 147; *pectoralis, part c*, G. & T., p. 30.

Mivart again gives an inaccurate origin: "from the sternum between the second and sixth costal cartilages." Gorham and Tower agree with Mivart.

The fifth pectoral, the most posterior member of the group, is long and comparatively narrow. The muscle arises from the aponeurosis of the *external oblique*, which here forms a ventral covering for the *rectus abdominis*. In the anterior portion of the origin, the muscle fibres arise directly from the median line, where there is raphé common to the several muscles of the abdominal wall. Posteriorly, however, the muscle fibres arise from the aponeurosis, along a line which extends obliquely, in a dorsal and posterior direction, from the mid-ventral line.

The muscle is inserted by aponeurosis both into the bicipital arch, and the proximal end of the humerus. The latter insertion includes both tuberosities.

Synonymy. *Second chef du grand pectoral*, S.-D., vol. II, p. 341; *xiphi-humeralis*, W. & G., p. 244; *pectoralis, part 4*, M., p. 147; *pectorals, part d*, G. & T., p. 31.

The details of the origin of this muscle are doubtless variable. Wilder & Gage state that the muscle fibres are connected to the median raphé by a thin, wide tendon. Mivart is, however, entirely mistaken as to the origin. He gives the muscle as arising "from the sternum between the fifth costal cartilage and the root of the xiphoid." Gorham and Tower give the same origin as Mivart: "from the sternum between the cartilages of the fifth and eighth ribs."

SOME MUSCLES OF THE HIND-LEG AND BACK.

Tensor vaginæ femoris. The muscle arises from the anterior end of the ilium, and from the fascia ex-

tending between this muscle and the anterior division of the *gluteus maximus*. This fascia is closely bound to the underlying *gluteus medius*, and is continuous with the dense fascia covering the sacrum dorsally.

The muscle is inserted by a fascia (*fascia lata*), which covers the external and anterior surface of the thigh, and dipping in between the *vastus externus* and the *adductor*, is attached to the outer surface of the femur, along nearly its whole length.

The *tensor vaginæ* near its origin, is inseparably connected (in cases at least) with the *gluteus medius*. It is also directly continuous posteriorly with the anterior division of the *gluteus maximus*, the two actually forming a single muscle.

Synonymy. *Couturier et droit interne* plus the *fascialis*, S.-D., vol. II, p. 402, p. 403; *tensor vaginæ femoris*, M., p. 154; *ditto*, G. & T., p. 39.

Gluteus maximus. The muscle is divided into two portions. The anterior arises directly by muscle fibres from the transverse process (lateral mass) of the third sacral vertebra, and the transverse process of the first caudal vertebra, and from the fascia covering the *gluteus medius* and the sacral region. It is inserted into the femur, just below the great trochanter, by means of the extreme upper end of the *fascia lata*, and by a few independent fibrous strands, noticeable in old subjects.

The posterior part arises directly by muscle fibres from the transverse processes of the first two caudal vertebrae. It is inserted into the *fascia lata*.

It is only in young subjects that the two parts of the muscle are distinct at the origin. In older subjects, the muscle has a continuous origin from the sacral fascia, sacrum and caudal vertebrae.

Synonymy. Fesser plus the paraméral, S.-D., vol. II, p. 395; gluteus maximus, M., p. 154; gluteus maximus, G. & T., p. 39.

The fesser of S. D. corresponds to our anterior portion of the muscle, though S. D. omits the origin from the third sacral vertebra. The paraméral of S.-D. corresponds to our posterior portion. Here again we differ slightly from S. D. regarding the origin, which according to him is from the second and third caudal vertebrae. The difference may easily be due to variation.

Quadratus lumborum. The muscle arises directly by its fibres, and also by tendinous origins, from the dorsal part of the anterior border of the ilium; and from the transverse processes of all the lumbar vertebrae. The fibres of the muscle run forwards and inwards mesially, and are inserted both directly and by means of narrow tendons into the centra of all the lumbar and the posterior three dorsal vertebrae.

This muscle exhibits a remnant of the metamerism, characteristic of the trunk muscles of the embryo and lower vertebrates, in that the narrow tendons are inserted successively into the bodies of the vertebrae, thus imperfectly dividing the muscle into myotomes.

Synonymy. Longs-sous-intertransversaires de lombes, S.-D., vol. II, p. 282; quadratus lumborum, M., p. 156.

Psoas magnus. The muscle arises directly by its fibres from the dorsal part of the anterior border of the ilium; by a few fibres from the transverse process of the last lumbar vertebra; at the extreme anterior end, externally, from the aponeurosis covering the quadratus lumborum; along its inner border from the centra of the lumbar vertebrae. Over its dorsal sur-

face the fibres of the muscle pass into the quadratus lumborum, with which muscle the psoas magnus is blended anteriorly, excepting that part which arises from the aponeurosis covering the former. The muscle is inserted on the lesser trochanter of the femur.

Synonymy. Psoas, S.-D., vol. II, p. 406; psoas magnus plus iliacus, M., p. 156; psoas magnus, G. & T., p. 42.

The fibres arising from the anterior border of the ilium correspond to Mivart's iliacus. M. is wrong in stating that the muscle arises "from the transverse processes of all the lumbar vertebrae." Gorham and Tower make the same statement.

Psoas parvus. This muscle may be regarded as a part of the psoas magnus, which has a separate insertion. It is indistinguishably united with the p. magnus throughout its anterior portion, and thus has with the latter a common origin. It is inserted by a tendon on the rim of the pelvis, at the ileo-pectineal eminence.

Synonymy. Mipsoas, S.-D., vol. 2. p. 287; psoas parvus, M., p. 156.

University of North Carolina,
February, 1896,

ORIGIN OF THE PERIDOTITES OF THE SOUTHERN APPALACHIANS.*

BY J. VOLNEY LEWIS.

INTRODUCTORY NOTE.

It was my privilege to spend the summer months of 1893, 1894 and a part of 1895 in mapping and studying in the field that portion of the Appalachian belt of peridotites which extends across North Carolina, almost parallel to its western boundary, from Virginia to Georgia and western South Carolina. A number of excursions were also made to other portions of the belt in Georgia and Pennsylvania. The work was done in the preparation of a report on "Corundum and the Basic Magnesian Rocks of Western North Carolina," which has just appeared as Bulletin No. 11 of the State Geological Survey. The Bulletin was confined to a presentation of the field results; the various rock types are described and the distribution and modes of occurrence of the peridotites and corundum are given in some detail.

Discussion of doubtful points, and especially of those already involved in controversy, was withheld for a future publication, in which the results of microscopic study and other laboratory work on these rocks would be presented, with such discussion of origin and other relations as these results might justify. A portion of this work has already been done, and some interesting results have been attained, but they will

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hardly be ready to put into systematic form for publication before the close of the year. A number of points have been brought out in the field-work, however, that are considered to have sufficient bearing on the origin of the peridotites to warrant their presentation.

THE ROCKS AND THEIR RELATIONS.

The accompanying map of the Appalachian crystalline belt (Plate I) shows the distribution of the peridotites throughout this region. In Pennsylvania and Maryland the basic magnesian rocks, whether originally peridotites or pyroxenites, have been entirely altered into serpentine; and hence have lost most of their original characteristics. The Virginia occurrences are not so well known. Rogers' Reports show that many of them have altered into serpentine and talcose rocks, and this is doubtless true of the great majority of outcrops. Fresh olivine rocks, however, are found passing over into that state from Alleghany county, North Carolina, and they are doubtless to be found at a number of places on the belt, south of Lynchburg.

With few exceptions, the peridotites south of Virginia are remarkably fresh, the alterations consisting, in the majority of cases, of scarcely more than surface discoloration or an occasional local change into massive serpentine.

The country rocks of the region are gneisses and mica schists, sometimes bearing considerable bodies of sheared and massive granites. The lamination has a prevailing strike of north 30° to 45° east and dips at high angles either northwest or southeast, often passing through the vertical from one to the other within the space of a few feet. Constituting a small proportion of the area of this region are the rocks of the per-

idotite belt, which occur typically in blunt lenticular form with a longer axis of from a few hundred to a thousand feet or more and oriented with the lamination in the surrounding gneiss. Sometimes they take the form of narrow strips two or three miles in length.*

Three types of magnesian rocks are found in this belt: namely, *peridotites*, *pyroxenites*, and *amphibolites*, characterized by the predominance of olivine, pyroxene and hornblende respectively. Pyroxenites and amphibolite frequently occur in small masses in close association with peridotites, and sometimes form important independent masses, but probably more than nine-tenths of the outcrops are peridotites.

The Peridotites.—The accepted classification of these rocks is used here merely as a matter of convenience. No such division into distinct classes is possible in the field; and the names here given represent simply mineralogic varieties of the same petrographic unit. Occasionally these varieties form separate masses, but generally they grade insensibly into each other, and sometimes within the limits of a single small outcrop. *Dunite*, essentially the pure olivine rock, with accessory chromite or picotite, is by far the most important, since it constitutes almost the entire body of a great majority of outcrops. *Harzburgite* (Saxonite), the olivine-enstatite rock, constitutes large masses in some of the northwestern counties of North Carolina, but it is usually found as a local variety of dunite. "Peridosteate" and "glinkite" seem to be only partially altered forms of this rock, consisting of large olivine crystals (or serpentine) and talc. *Amphibole-picrite*,

* See map (Plate I) published in Bull. 11, N. C. Geological Survey, 1895.

the olivine-actinolite variety, has been observed only in connection with dunite, though some chloritic olivine rocks are doubtless altered forms of this variety. *Troctolite* (forellenstein) consists essentially of olivine and anorthite, with zones of intermediate fibrous minerals always separating them, and sometimes also bears large dark hornblende. By gradual transition it passes, on the one hand, into dunite, and, on the other, into the feldspar type *anorthosite*.

The Pyroxenites.—This class is represented by two types, which seem to be quite distinct, as no transitional forms have yet been found. *Enstatite-rock*, as the name indicates, is composed of orthorhombic pyroxene, and seldom contains any other mineral in prominent proportions. It often occurs in small masses with dunite and harzburgite, though considerable outcrops in some localities are composed of it entirely. In some of these instances there is apparently evidence of its origin from peridotites. *Websterite*, the enstatite-diopside type, is found in the midst of the peridotites about Webster, Jackson county, North Carolina. This type was first recognized and described by the late Dr. G. H. Williams,* and similar rocks were studied from Baltimore county, Maryland, where transitional forms were found connecting it with peridotites, bronzitite, gabbros, and norite. At the Webster locality, however, no such intermediate types have been observed.

Amphibolite.—Only one type of this class has been found in the peridotite belt. It is composed of a brilliant, grass-green, aluminous amphibole, which often bears considerable anorthite and is only occasionally

* *Am. Geologist*, VI, 1890, 40-49,

massive, generally presenting a gneissic lamination. The amphibole constituent has long been erroneously called "smaragdite," solely on account of its color. Analyses show over 17 per cent. of alumina, and Professor Dana calls it *edenite* in his new "System of Mineralogy." This rock forms dikes in the peridotites at Buck Creek, Clay county, North Carolina, and is associated with peridotites in many places in this and the neighboring counties of Georgia.

No absolute contacts have been observed between the peridotites or pyroxenites and the enclosing gneiss. There is always a border of schistose talc, from two to three feet in thickness, developed between them. Often there is also a variable zone of chlorite or vermiculite, or of both together, intervening between the talc and the peridotite mass; and in many cases this bears corundum in considerable quantity.*

EVIDENCE BEARING ON ORIGIN.

We have seen that the peridotites occur, as a rule, in lenticular masses and sheets, having their longer axes oriented with the lamination of the gneisses and schists of the country. Some of these lenses are short and blunt, and occasionally the outcrops present a very irregular outline and cover areas of several hundred acres, as at Buck Creek, in Clay county, North Carolina (Plate II). The smaller masses are in just the form one would expect to find in small intrusions of molten magma into thoroughly laminated crystalline

* For more detailed description of the rocks and modes of occurrence and distribution of both the peridotites and corundum, the reader is referred to "Corundum and the Basic Magnesian Rocks of Western North Carolina," *Bulletin 11, N. C. Geol. Survey.* and to "Corundum of the Appalachian Crystalline Belt," *Trans. Am. Inst. Mining Engineers*, XXV, Atlanta Meeting, 1895.

rocks; and the more irregular outlines would naturally have been produced by larger intrusions accompanied or preceded by intense folding and contorsion of the gneisses. Furthermore, both the irregular and the more typical lenticular outcrops frequently present a forked outline or send off small apophyses into the gneiss in such a way as would be wholly inexplicable in a rock of sedimentary origin. Prominent examples of this character are presented on the maps of Buck Creek, Corundum Hill and Webster areas (Plates II, III, and IV). A forked mass is found on the mountain slopes at the head of Eljay creek, Macon county, N. C., and a larger one on the spurs of Elk Ridge, in Ashe county. Several others of a similar nature might be added from North Carolina alone.

The planes of least resistance in gneiss lie along the lamination, and hence, as stated above, we should expect the axes of intrusive masses to coincide with these planes. This is found to be true in the great majority of cases, and the apparent exceptions are doubtful. The gneisses and schists bend closely around the enclosed mass, being only temporarily diverted from their normal course. The axes of the bifurcate masses are also found to follow the same general direction. (See Plate III).

The last requirement in geotectonic evidence would seem to be fully met by the gneiss area, more than a quarter of a mile long, entirely surrounded by peridotites, on the northern border of the Webster area. (Pl. IV). Indeed, this Webster region alone, though once made the basis of a theory of sedimentary origin for the peridotites,* affords some of the most conclusive

* "The Dunite Beds of North Carolina," by A. A. Julian, *Proc. Nat. Hist. Soc., Boston*, XXII, 1882, 141-149.

evidence of their intrusive character. The form presented by the lamination planes of the gneiss is that of an eroded dome-shaped anticline, somewhat elongated in almost a north and south direction. Even after considerable observation in the field, it was my impression that the peridotites of this area represented a continuous sheet conformable with the lamination of the gneiss. But close, detailed mapping brought out not only the enclosed body of gneiss mentioned above, but also the irregular, protuberant apophysis at Addie, and other projecting arms at the crossing of Scott's creek, three miles west of Addie, and two in the vicinity of Webster. Furthermore, there are five distinct breaks in the continuity of the eastern side on Cane creek, and the isolated portions have the typical lenticular form found in the majority of the outcrops. In the vicinity of these breaks there is a narrow strip passing off the border of the map in a northeast direction, which is also completely disconnected from the principal masses of this region.

This Webster rock shows the highest development of lamination found in the whole belt, and the microscope shows that the laminated rock is composed of thin layers of finely granulated olivine alternating with coarser typical dunite. This condition, taken in connection with the great development of schistose talc in the narrower portions, gives evidence of considerable shearing, which is most naturally ascribed to the movements that gave rise to the anticlinal structure. The other characters pointed out are explicable only as the results of igneous intrusion.

Much larger areas of gneiss than those enclosed at Webster are almost surrounded in the Buck creek area by the peridotites and the later dikes of amphibolite.

The manner in which these dikes cut the peridotites or pass up through the same opening beside them, both in this region and in a number of places in the adjoining portions of Georgia, clearly indicates that the peridotites occupy areas of weakness in the gneiss, through which the dikes have found their easiest exit. It may be stated here that no direct influence of the amphibolite dikes upon the dunite was noted except an intermingling of the constituents of the two rocks along bands of three or four inches in thickness at the contacts.

Another character which is perhaps as important as that of form, is the entire absence of lamination, or its development to only a slight extent, in the great majority of peridotite outcrops. Dr. Julian, as noted above, studied the outcrop at Webster, where the lamination is so marked that the dunite bears a striking resemblance to a thin-bedded sandstone; and this is, in fact, what Dr. Julian considered it to be. As pointed out by Dr. Wadsworth, however, "the chief defect in Dr. Julian's reasoning is that all the evidence which he gives in support of this view could exist equally well if the rock had some entirely different origin."* If Dr. Julian had only studied some of the typical massive dunite to be found within a day's journey of Webster, it is safe to say that his conclusion on this point would have been entirely different.

Aside from the lamination in the body of the peridotite, there is often abundant evidence that it has been subjected to considerable shearing in the schistose character of the talc along the borders and in the frequent slickensides encountered in the corundum-bearing chlo-

* *Science*, III, 1884, 486, 487.

rite zones. On the other hand, we find many outcrops that present none of these evidences of shearing, but are perfectly massive and structureless; and we must conclude that these represent the least altered condition of the rock. The massive character of the peridotites, with often scarcely a trace of shearing, is wholly incompatible with the theory that they are of contemporaneous origin with the gneiss and have passed through the same cycles of disturbance.

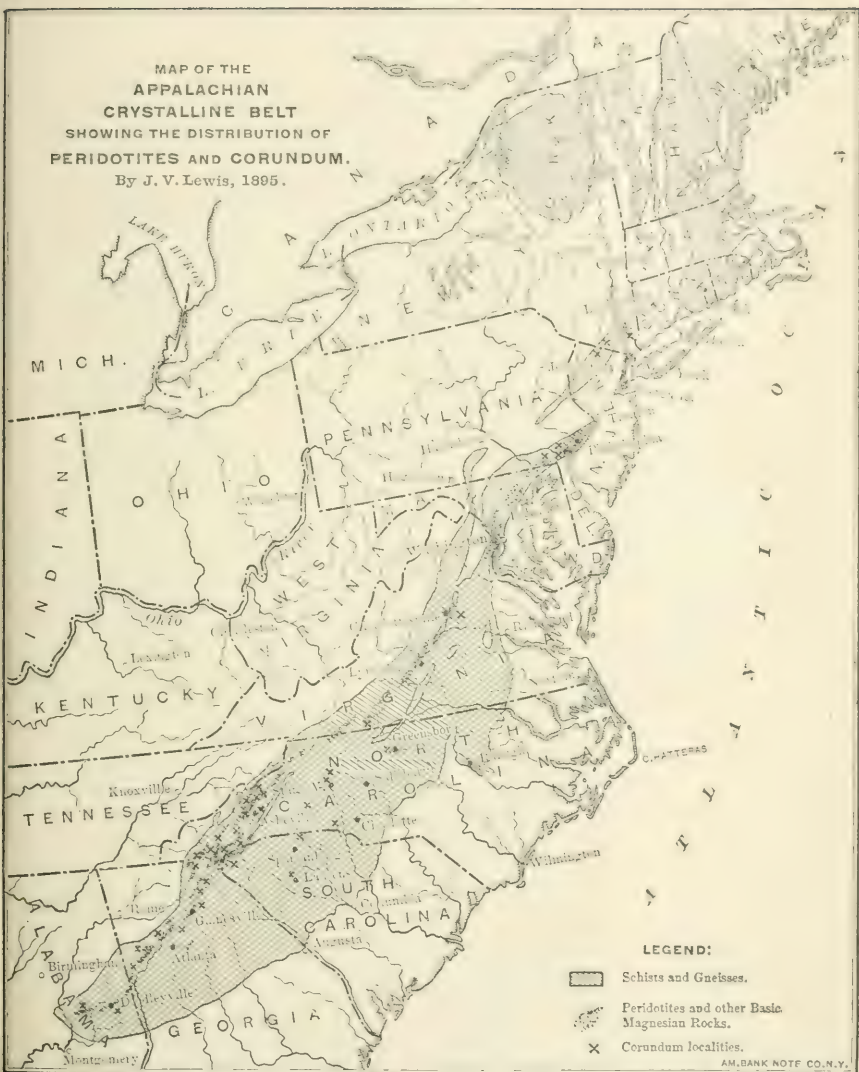
The line of separation between the peridotites and the gneiss is always sharp; there are no transitional forms, either in chemical or mineralogical composition. The peridotites are extremely basic magnesian rocks (40-45 per cent. silica); the constituents of the gneiss are all aluminous minerals, and the rock is highly acid (60-70 per cent silica). That such dissimilar rocks would have been deposited as contemporaneous sediments or precipitates over wide areas without somewhere producing an intermediate type is, at least, highly improbable.

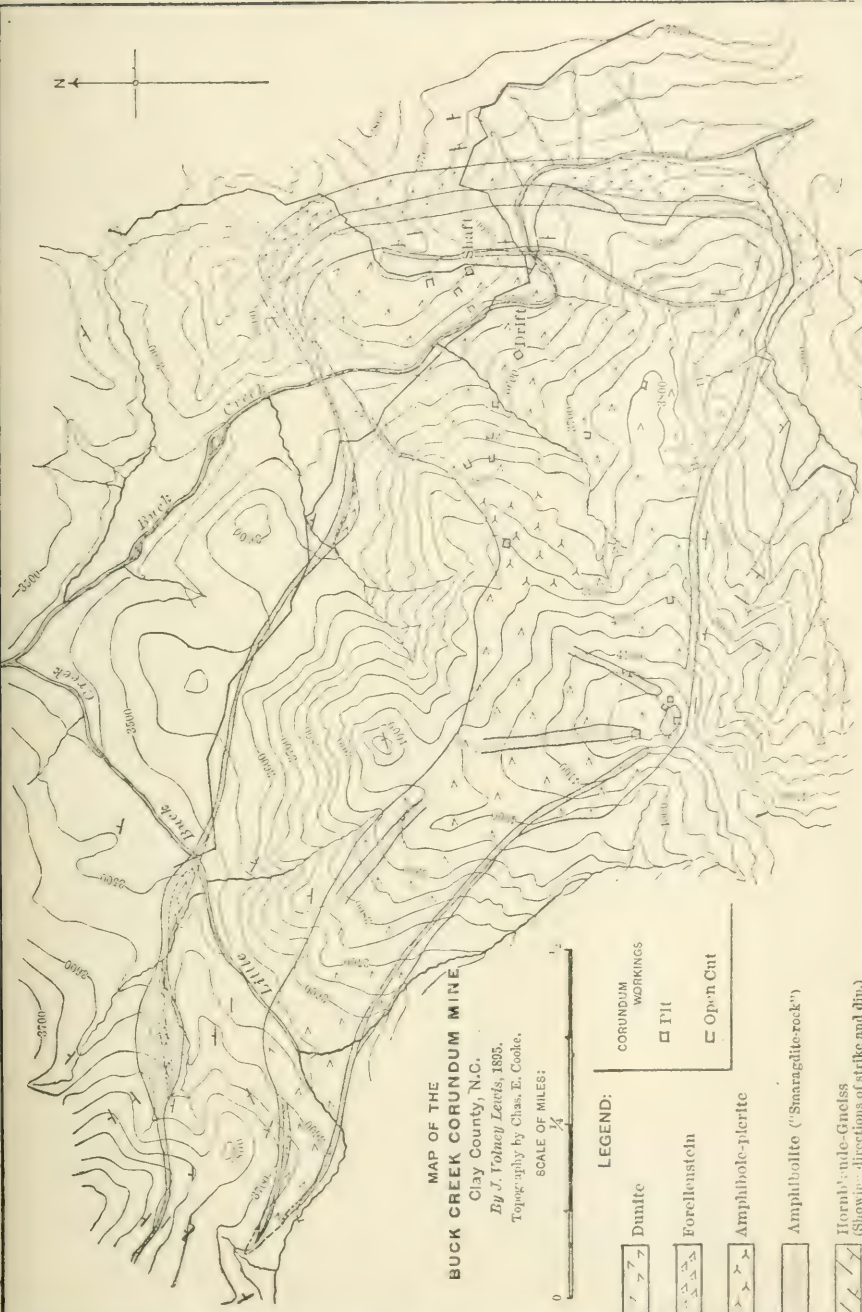
Even a mere casual examination of these rocks with the microscope reveals a thoroughly crystalline granular structure, generally a coarse texture, and in all respects the characteristics of a deep-seated, igneous rock. In fresh specimens the olivine grains always present angular outlines, sometimes having crystal form, and always fitting perfectly together, without interstitial spaces or cementing material of any kind. (Pl. V., fig. 1. In the first stage of alteration to serpentine the grains are separated by thin films of this mineral; but the irregularities of adjacent grains still remain perfect counterparts. (Pl. V, fig. 2.). Only in the more advanced stages do the corners become rounded and the intervening serpentine assume the appearance

PLATE I.

MAP OF THE
APPALACHIAN
CRYSTALLINE BELT
SHOWING THE DISTRIBUTION OF
PERIDOTITES AND CORUNDUM.

By J. V. Lewis, 1895.





MAP OF THE
BUCK CREEK CORUNDUM MINE

Clay County, N.C.

By J. Volney Lewis, 1895.

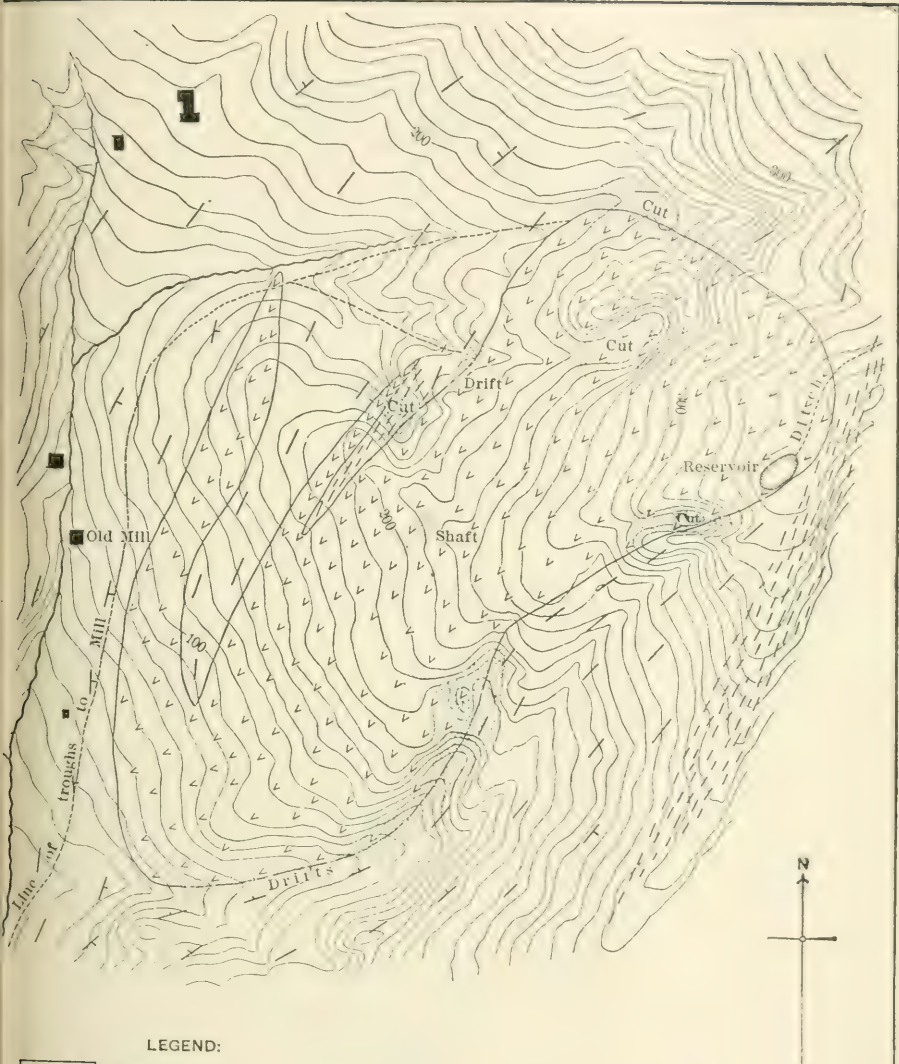
Topography by Chas. E. Cooke.

SCALE OF MILES:



LEGEND:

- | | | | |
|--|----------------------------------|--|-------------------|
| | Dunite | | CORUNDUM WORKINGS |
| | Forcellenstsch | | Pli |
| | Amphibole-plerite | | Open Cut |
| | Amphibolite ("Smaragdlite-rock") | | |
| | Hornblende-Gneiss | | |
- (Showing directions of strike and dip.)



LEGEND:



Dunite



Gneiss

(Showing directions of strike and dip.)



Mica-Schist



Corundum Workings

MAP OF
CORUNDUM HILL

Macon County, N.C.

By J. Volney Lewis, 1895.

Topography by Chas. E. Cooke.

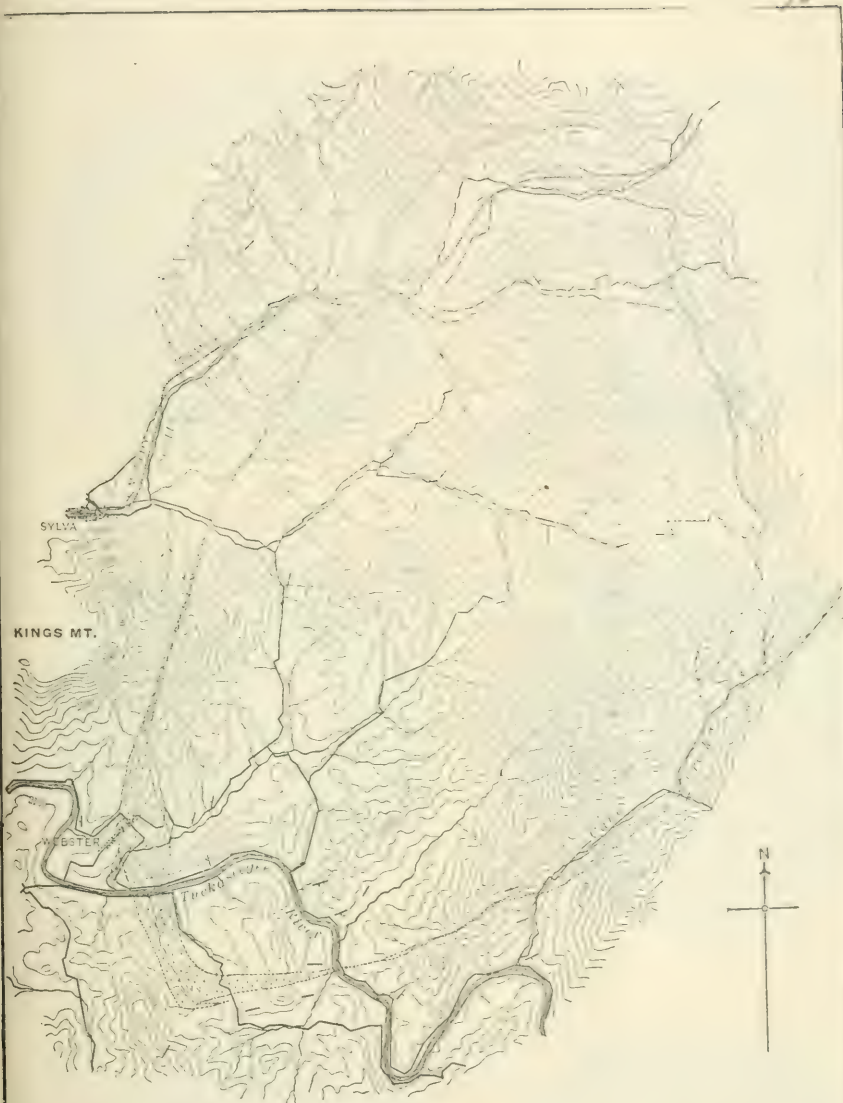
Contour Interval 10 feet.

SCALE OF FEET:





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FIGURES ON CONTOUR LINES GIVE ELEVATIONS ABOVE AN ARBITRARY BASE—THE FLAT ROCK BED OF THE BRANCH NEAR THE SOUTHWESTERN CORNER OF THE MAP.



LEGEND:

-  Dunite.
-  Websterite.
-  Talc-Schist.
-  Gneiss.
(Showing directions of strike and dip.)

MAP OF THE
WEBSTER PERIDOTITE AREA

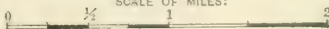
JACKSON COUNTY, N.C.

By J. Volney Lewis, 1895.

Topography by Chas. E. Cooke.

Contour interval 100 feet.

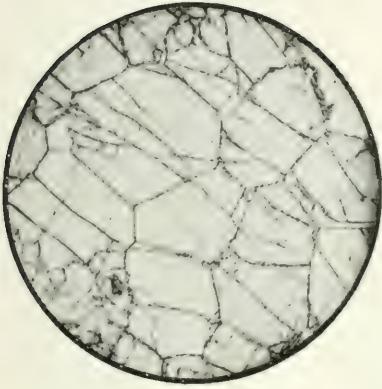
SCALE OF MILES:



ENGRAVED BY AMERICAN BANK NOTE CO., NEW YORK

FIGURES ON CONTOUR LINES GIVE ELEVATIONS ABOVE SEA LEVEL.

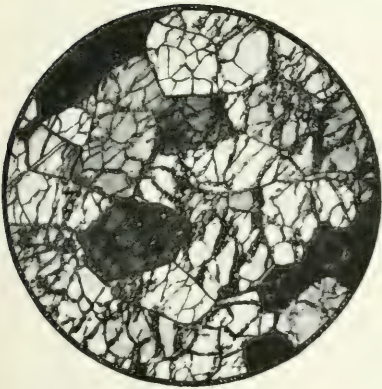
PLATE V.



1



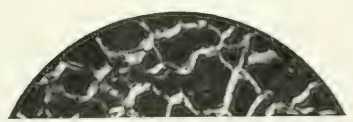
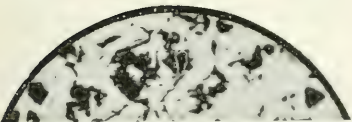
2



3



4



of a cementing material in a elastic rock; and this is true only when thin sections are viewed in ordinary light. (Pl. V, fig. 4.) For, so long as numerous olivine remnants remain embedded in the serpentine, they are frequently found to extinguish together over considerable areas, showing that the fragments belong to the same crystalline individual, representing the larger grains of the original rock. Such fragments may be as widely separated by the alteration product as are the portions of entirely distinct individuals. Even after all traces of unaltered olivine have disappeared, the original granular character, and occasionally the outline of a crystal form, are still shown in some of the serpentines by the narrow, reticulating bands ("mesh-structure") of parallel-polarizing, fibrous serpentine, representing the first stage of alteration along the borders and fissures of the olivine grains.

Plate V. is reproduced from photomicrographs of thin sections of typical dunite. A perfectly fresh specimen is shown in figure 1. Figure 2 shows a slight beginning of serpentinization about the borders of the olivine. Figure 3 is taken from a fresh specimen in which the original grains, like those in figure 1, have been broken into great numbers of smaller grains, without perceptibly disturbing their orientation; this section is seen between crossed nicols. A more advanced stage of alteration than that of figure 2 is shown in figure 4; the olivine grains, the light portions of the field, are reduced to mere remnants. Figure 5 represents the final result of serpentinization, in which no fragment of unaltered olivine remains. With the exception of spots caused by segregation of iron oxides, the rock appears perfectly homogeneous in ordinary light. When viewed between crossed nicols, however,

the 'mesh-structure' is distinctly brought out, and the original granular nature of the rock clearly seen, as shown in figure 6.

The variation between the different mineralogic varieties within the same rock mass, and the essential unity of the whole peridotite group, have been pointed out above in the descriptions of the various types. Dunite, harzburgite and enstatite rock are often found to blend into each other as inseparable parts of the same rock mass, with no banding or irregularity of structure, whatever, between the different types. These phenomena are such as are referred to magmatic segregation or differentiation in well recognized igneous rocks. In the enstatite bearing type, the crystals of this mineral are much larger than the grains of olivine and are in the form of broad, flat plates; yet, when the rock has not been sheared, no trace of parallel arrangement has been detected. Even when considerably sheared and laminated, only a partial parallelism has been effected between the enstatites, and they have usually been altered into talc.

Similar transitions from dunite to amphibole-pierite are found within the peridotite area at Buck Creek (Pl. II.). Here, too, and also throughout a considerable territory to the southwest, transitions are found from dunite, the pure olivine rock, to troctolite, the coarse olivine-feldspar type; and the latter, in turn, passes into the pure anorthite rock, anorthosite.

The extremely fresh condition of the olivine, even in the surface exposures, is a very striking feature of these peridotites. Most of them, it is true, show some tendency to serpentinization when examined with the microscope, and in a few cases they have undergone complete transformation; but a number of specimens

have been collected almost at the surface in which scarcely a trace of alteration could be seen. It is well known that olivine is remarkably prone to alteration, either to serpentine, through hydration, or to iron oxides and soluble carbonates, in ordinary surface weathering. Even if it might be conceived that a pre-existing olivine lava had been beaten down by the waves and deposited as beds of sand along the beach, as we are told actually occurs on some of the Hawaiian coasts, it would be extremely difficult to imagine this rock, with all its contained water, placed under conditions necessary to complete solidification into a sandstone, and carried through all the metamorphosing conditions that the enclosing gneisses have certainly undergone, and at last, by erosion to the very heart of the Appalachians, brought to the surface unaltered. With a sandstone of almost pure silica, I can imagine such an evolution possible; but with unstable olivine, the hypothesis seems entirely untenable.

The rapid rate of erosion in the mountain region and the ease with which the granular olivine rock crumbles down under surface weathering, may well account for the freshness of the present exposures. But beds of olivine sand are not formed under these conditions, even in the channels of neighboring streams. Hence, I am led to the conclusion that no theory of sedimentary origin can adequately account for existing conditions, and that these olivine rocks are now practically in the state in which they originally solidified from the molten magma.

SUMMARY OF EVIDENCE.

I have endeavored to show that the peridotites of the South Appalachian region must be regarded as plutonic igneous rocks for the following reasons:

(1) Their blunt, lenticular form is difficult to understand as the result of any kind of sedimentation, but is easily explained when they are considered as small intrusions into a highly laminated rock.

(2) In a number of cases apophyses are sent off into the enclosing gneiss—a condition that can be produced only by igneous action.

(3) In one case, at least, a large block is completely enclosed by the peridotites in such a manner as to preclude all hypotheses of sedimentation, and attributable only to the intrusion of the peridotites in a molten state.

(4) The lamination found in many cases which has been considered true bedding, is always accompanied by abundant evidence of shearing; and this is regarded as the most natural explanation of all such parallel structure in these rocks.

(5) At Buck Creek and in adjoining regions, both the main masses of the peridotites and their apophyses are accompanied by amphibolite dikes, showing that the former occupy positions of marked weakness in the gneisses.

(6) The massive character of the typical outcrops is incompatible with contemporaneous origin with the gneisses; for such character could not have been maintained through the intense metamorphosing processes to which the gneisses have been subjected.

(7) The extremely basic peridotites are enclosed in highly acid gneisses over an extensive territory, but they are everywhere perfectly separate—no transitional types are found.

(8) Under the microscope these peridotites show the typical granular structure of plutonic igneous rocks,

the grains fitting perfectly into each other without interstitial spaces or cementing material.

(9) The mineralogical varieties pass irregularly into each other without interlamination or any regularity of structure whatever. They present typical magmatic differentiation.

(10) The perfectly fresh condition of the olivine, a mineral so prone to alteration, is incompatible with any theory of sedimentation with subsequent solidification, metamorphism and erosion.

Chapel Hill, N. C..

Feb 1, 1896.

EXPLANATION OF PLATE V.

Fig. 1. Specimen from railroad cut 2 miles west of Balsam Gap, Jackson, Co., N. C.

This is an exceptionally fresh specimen of the pure olivine type. Crystal outlines are rather more common in this section than usual.

Fig. 2. Specimen from Carter Corundum Mine, Madison Co., N. C.

This figure represents the prevailing character of the surface exposures of dunite. The first narrow bands of yellowish green serpentine, which afterwards constitute the 'mesh-structure' have just been formed.

Fig. 3. Specimen from Carter Corundum Mine, Madison Co., N. C.

This section shows a common type of fine grained dunite. It is here seen between crossed nicols, and the extinction together of the fine grains over considerable areas shows that it is essentially a coarse-grained rock, like that shown in Fig. 1.

Fig. 4. Specimen from Webster, Jackson Co., N. C.

This specimen shows an advanced stage in serpentinization, the beginning of which is shown in figure 2. Rejected iron oxides have been deposited in dark bands about the olivine remnants.

Fig. 5. Specimen from Paint Fork, Madison Co., N. C.

No olivine fragments are found in this specimen. Except for the black accumulations of iron oxides, the rock looks homogeneous in ordinary light.

Fig. 6. Specimen the same as for Fig. 5.

This figure is identical with the last, except that it is here seen between crossed nicols. The 'mesh-structure' outlining the original olivine grains is well shown. (The view is inverted with reference to figure 5.)

MONAZITE*

BY H. B. C. NITZE.

During the past two years the mineral monazite has come into considerable prominence, owing to the demand for it in the manufacture of mantles for the incandescent gas light, which is at present creating such wide spread interest the world over.

In Bulletin No. 9 of the North Carolina Geological Survey, 1895, I have published a monograph on the subject of Monazite and the Monazite Deposits of North Carolina, and a similar chapter also appears by me in "The Mineral Resources of the United States," Part IV., Sixteenth Annual Report of the Director of the U. S. Geological Survey, 1894-1895, pp. 667 to 694.

In this place I propose to give a general resumé of monazite, its properties, composition, occurrence and use.

NOMENCLATURE.

The earliest identification of this mineral as a separate species in the mineral kingdom was in 1823, although at that time it was known as "Turnerite." The name monazite was given in 1829, and its meaning—from the Greek—is, "to be solitary," on account of the great rarity of the mineral at that time and long subsequently. Other names for this mineral, given at various times when they were thought to represent separate and distinct species, were mengite, cremite, edwardsite, cryptolite, monazitoid, phosphocerite, ur-

* Published by permission of the State Geologist of North Carolina, who also allows the use of plates prepared for Bulletin 9 of the N. C. Geological Survey.

dite and kararfveite. These were all shown, by the patient investigations of renowned mineralogists, to be identical with monazite, and that name was retained because at the time it was given it represented a crystallographically as well as chemically known mineral, while the attributes of the others were not so well established until later. And so the name monazite is in common use to-day.

CHEMICAL COMPOSITION.

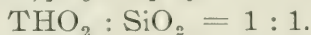
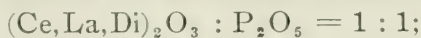
Chemically, monazite is an anhydrous phosphate of cerium, lanthanum and didymium. It also contains, almost invariably, small percentages of thorium and silica; and some of the more complete analyses have shown the presence of yttria, erbia, alumina, ferrous and ferric oxide, lime, magnesia, manganese, tin and lead oxides, fluorine, zirconia, tantalum and titanum acids. Undoubtedly most of these latter existed as impurities, in all probability, attached to the monazite. Below are given a few detailed analyses from various localities.

ANALYSES OF MONAZITE.

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|--------------------------------|-------|-------|-------|-------|-------|-------|-------|-------|
| P ₂ O ₅ | 23.62 | 27.07 | 23.85 | 27.28 | 17.94 | 23.78 | 26.86 | 29.28 |
| Ce ₂ O ₃ | 32.52 | 25.82 | 27.73 | 30.46 | | 27.73 | 24.80 | 31.38 |
| La ₂ O ₃ | 29.41 | 30.62 | 21.96 | 24.37 | 21.30 | 39.24 | 26.41 | 30.88 |
| Di ₂ O ₃ | | | | | | | | |
| Y ₂ O ₃ | 2.04 | 2.03 | 2.86 | 1.58 | | | | |
| ThO ₂ | 4.54 | 9.60 | 9.05 | 11.57 | | | 12.60 | 6.49 |
| SiO ₂ | 1.51 | 1.85 | 5.95 | 2.02 | | 1.60 | .91 | 1.40 |
| Al ₂ O ₃ | .22 | .15 | | | | | | |
| Fe ₂ O ₃ | .36 | 1.01 | 4.63 | | trace | 1.30 | 1.07 | |
| FeO | | | | 1.10 | | | | |
| MnO | | .08 | | .24 | | | | |
| CaO | .84 | .91 | 4.83 | 1.05 | 1.50 | .90 | | |
| MgO | | .03 | | | trace | | .04 | |
| ZrO ₂ | | | .66 | | | | 1.54 | |
| SnO ₂ | .22 | | | .08 | | | | |
| PbO | | .58 | | .26 | | | | |
| Ta ₂ O ₅ | | | | | 6.27 | | | |
| F | | | | | | | | |
| TiO ₂ | | | | | | | | |
| H ₂ O | .27 | .35 | 1.61 | .38 | 1.36 | | .78 | .20 |
| CeO | | | | | 49.35 | | | |
| Er ₂ O ₃ | | | | | | | 4.76 | |

(1) to (4) inclusive are from pegmatite veins of southern Norway, by C. W. Blomstrand. (5) From Lake Ilmen, Russia, by R. Hermann. (6) From Arendal, Sweden, by C. F. Rammelsberg. (7) From Ottawa County, Quebec, by F. A. Genth. (8) From Burke County, N. C., by S. L. Penfield.

Penfield* deduces the molecular formula:



The former corresponds to the normal phosphate of the cerium metals ($\text{R}_2\text{P}_2\text{O}_8$); the latter corresponds to the normal thorium silicate, which, in combination with a small percentage of water, makes the mineral thorite or orangite ($\text{ThSiO}_4 \cdot \text{H}_2\text{O}$). He concludes, therefore, that monazite is essentially a normal phosphate of the cerium metals, in which thorium silicate is present in varying proportions as an impurity in the form of the mineral thorite or orangite.

Dunnington† had somewhat previously come to the same conclusion. Rammelsberg's‡ formula of thorium free monazite from Arendal, Norway, was $\text{R}_2\text{P}_2\text{O}_8 = (\text{Ce, La, Di})_2\text{P}_2\text{O}_8$, thus agreeing with Penfield.

Blomstrand,§ from his analysis of Norwegian and Siberian monazite concludes that the mineral is a normal tri-basic phosphate, an excess of bases being combined with SiO_2 . Thus: $m(3\text{RO}, \text{P}_2\text{O}_5) + 2\text{RO}, \text{SiO}_2 + p\text{H}_2\text{O}$, where $m = 5$ to 20, and $p =$ less than 1 usually.

He does not believe, as Penfield does, that the thoria is originally combined with silica as thorite, but that

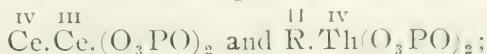
* Am. Jour. Sci. (3) vol. XXIV, 1882, p. 250; vol. XXXVI, 1888, p. 322. Zeitschr. für Kryst., vol. VII, 1883, p. 366; vol. XVII, 1890, p. 407.

† Am. Chem. Jour., vol. IV, 1882, p. 138.

‡ Zeitschr. Deutch. Geol. Gesell. Berlin vol. XXIX, 1877, p. 79.; Zeitschr. für Kryst., vol. III, 1879, p. 101.

§ Zeitschr. für Kryst., vol. IX, 1887, p. 160; vol. XX, 1892, p. 367.

it is present as a phosphate, either in combination with the cerium or as an isomorphous mixture, thus:



and that it is altered to the silicate by siliceous waters.

PHYSICAL PROPERTIES.

The crystallographic form of monazite is monoclinic, and the commonly occurring planes are ortho- and clino-pinacoids and domes, the unit prism and the unit pyramid. The basal pinacoid is rare, having been observed only on crystals from the Urals and from Alexander County, N. C.

The usual crystal habit is tabular, parallel to the ortho-pinacoid; also short columnar, and sometimes elongated parallel to the prism. Twins are not common, the twinning plane being usually parallel to the ortho-pinacoid.

These crystals vary in size from the microscopic needles of cryptolite, which have a thickness of 0.00015 to 0.00062 inch, to the abnormally large crystals of Amelia County, Va., 5 inches in length. The more general variation lies between $\frac{1}{20}$ and 1 inch.

The cleavage of monazite is most perfectly developed parallel to the basal pinacoid, it is also distinct, as a rule, parallel to the ortho-pinacoid; and sometimes visible parallel to the clino-pinacoid. The mineral is brittle, with a conchoidal to uneven fracture; the hardness is 5 to 5.5; specific gravity 4.64 to 5.3; lustre resinous to waxy; the crystal faces are splendid in fresh, pure specimens, dull in weathered, impure specimens; the color is honey yellow, yellowish brown, amber brown, reddish brown, brown or greenish yellow; the purest specimens are transparent, becoming translucent, and even opaque in the impure varieties.

The optical properties of monazite are:—thin sections, by transmitted light, are colorless to yellowish; pleochroism is generally scarcely noticeable; absorption b is greater than $c = a$; the plane of the optic axis is perpendicular to the plane of symmetry, that is the clino-pinacoid, the positive acute bisectrix lies in the oblique angle β , hence sections parallel to the basal pinacoid show the full interference figure; the extinction angle varies from $1^{\circ}04'$ to $5^{\circ}54'$; the optical angle is small, $2E$ (red) = $25^{\circ}22'$, $2E$ (yellow) = $24^{\circ}56'$, $2V$ (yellow) = $12^{\circ}44'$, (from Schüttenhofen, Bohemia); the dispersion is weak and horizontal; the single refraction is high, and the double refraction considerable, $\gamma - a = 0.0454$, $\gamma - \beta 0.0446$, $\beta - a = 0.0008$ (from Arendal, Norway).

DISTRIBUTION AND MODES OF OCCURRENCE.

Until comparatively recently the localities in which monazite was found were few and far between. The original specimen of turnerite came from the Dauphiné in France; in 1826 Menge discovered some crystals in the Ilmen Mountains of Russia; it was then found in the United States at Norwich and Watertown, Conn. Up to the present time, it has been found in over 75 localities in the United States, Canada, South America, England, Sweden, Norway, Finnish Lapmark, Russia, Belgium, France, Switzerland, Germany, Austria and Australia. And the probabilities are that these localities will be rapidly added to in the future.

Monazite is an accessory constituent of the granite eruptives and their derived gneisses. It has been found in these rocks over widely separated areas of the Earth's surface, and further search and study is liable to reveal its more general presence in similar rocks,

than was formerly supposed. Thus Derby,* by examining the heavy residues of a number of hand specimens, selected at random from the collection in the National Museum at Washington, D. C., described the occurrence of monazite in certain granites and gneisses of Maine, New Hampshire, Rhode Island and Massachusetts.

In Norway, Silesia and Bohemia, and in some of the mica mines of Canada, Virginia and North Carolina, monazite has been found in pegmatite dikes. Derby has found the mineral in a red syenite at Serra do Stauba, in the province of Bahia, Brazil. The turnerite of the Saacher Lee (which is an extinct volcanic crater) near Coblenz, in Prussia, was found in a druse in a sanadine bomb, the only known occurrence of monazite in an undoubted volcanic rock.

The turnerite of Olivone, Switzerland, occurs in a quartz vein 20 to 30 cm. wide, traversing crystalline schists.

The cryptolite of Norway occurs as inclusions of very fine, needle-shaped crystals in apatite.

In Cleveland County, N. C., monazite has been found intergrown in cyanite.

The percentage of monazite in these rocks is exceedingly small, often infinitesimal; thus Derby* states that the granite dikes of Serra de Tingua, near Rio, are rich in the yellow mineral, carrying 0.02 to 0.03 per cent, and a fine-grained granite dike on the outskirts of Rio de Janeiro, showed 0.07 per cent monazite.

Monazite has not been found in the sedimentary rocks, although it may be present in some of these as a secondary mineral of transportation.

* Proc. Rochester Acad. Sci., vol. I, 1891, p. 294.

* Proo. Rochester Acad. Sci. vol. I, 1891, p. 294.

The monazite is contained in the main constituents of the granitic rocks, in the quartz, feldspar and mica, though it appears to be more generally confined to the feldspar.

Zircon may be regarded as a constant associate; among the other usually associated minerals, of coeval origin with the monazite, are xenotime, fergusonite, sphene, rutile, brookite, ilmenite, cassiterite, magnetite, and apatite; sometimes beryl, tourmaline, cyanite, corundum, columbite, samarskite, uraninite, gummite, autunite, gadolinite, hielmite and orthite.

Among the principal secondary minerals found in association with monazite, are rutile, brookite, anatase, epidote, orthite, garnet, sillimanite, and staurolite.

The economically valuable deposits of monazite are found in the placer sands of streams and rivers, in the irregular sedimentary sand deposits of the adjoining bottom lands and in the beach sands along the seashore.

The decomposition and disintegration of the crystalline rocks, the original source of the mineral, has proceeded to considerable depths in certain localities, particularly in the southern unglaciated countries. By erosion and secular movement the material is deposited in the stream beds and there undergoes a natural process of sorting and concentration, the heavy minerals being deposited first and together. The richer portions of these stream deposits are thus found near the headwaters. The accompanying plate shows one of these small valleys (Lattimore's), three miles northeast of Shelby, N. C., where all of the underlying gravel is being dug and washed for monazite (see also plate facing p.), and where the sand in the bed of the small stream is also being washed for the same purpose. The geographical areas over which such work-

able deposits have been found up to the present time, are quite limited in number and extent.

In the United States the placer deposits of North and South Carolina stand alone. Similar deposits exist in the provinces of Bahia, Minas Geraes, Sao Paulo, and Rio de Janeiro, Brazil; in the river sands of Buenos Ayres, Argentine Republic; in the gold placers of Rio Chico, at Antioquia, Colombia; and in the Bakakui placers of the Sanarka River, Russia. In Brazil there are also important deposits in the beach sands in the southern part of the province of Bahia, near the island of Alcobaca.

But little reliable information is at hand concerning these foreign deposits, and the remainder of the present paper will be taken up with a description of the Carolinian deposits, and the methods of mining and cleaning the sand, employed there.

The Carolinian area includes between 1600 and 2000 square miles, situated in Burke, McDowell, Rutherford, Cleveland, and Polk Counties, N. C., and the northern part of Spartanburg County, S. C. The principal deposits of this region are found along the waters of Silver, South Muddy, and North Muddy creeks, and Henry's and Jacob's forks of the Catawba River in McDowell and Burke counties; the Second Broad River in McDowell and Rutherford counties; and the First Broad in Rutherford and Cleveland counties, N. C., and Spartanburg County, S. C. These streams have their source in the South Mountains, an eastern outlier of the Blue Ridge. The general outlines of this area are indicated on the accompanying map.

The country rock is granitic biotite gneiss and dioritic hornblende gneiss. The existence of monazite

here in commercial quantities was first established in 1887. The thickness of these stream gravel deposits is from one to two feet. The percentage of monazite in the original sand is very variable, from an infinitesimal quantity to one or two per cent.

WASHING AND CLEANING MONAZITE SAND.

The monazite is won by washing the material in sluice boxes, about 8 feet long by 20 inches wide by 20 inches deep, exactly after the manner that placer gold is worked. Magnetite, if present, is eliminated from the dried, concentrated sand by treatment with a large hand magnet. Many of the heavy minerals such as zircon, menaccanite, rutile, brookite, corundum, garnet, etc., cannot at present be completely separated. The commercially prepared sand, therefore, is not *pure* monazite. A cleaned sand, containing from 65 to 70 per cent. monazite is considered of good quality.

The most systematic washing method employed is by the use of two sluice boxes, the mouth of one discharging into the head of the other, placed below. The gravel is charged on a perforated plate at the head of the upper box, and the clean up is so thoroughly washed as to give a high grade sand, often up to 85 per cent. pure. The tailings discharge directly into the lower box, where they are rewashed, producing a second grade sand. At times the material is subjected to as many as five similar consecutive washing treatments in the sluice boxes. A further concentration of the dried washed sand is sometimes made by pouring from a cup in a fine, steady stream from a height of about 4 feet, on to a level platform: the lighter quartz and black sand, with the fine grains of monazite (tailings) fall on the periphery of the conical pile and are constantly brushed aside with hand brushes; these tailings are

afterwards rewashed. Or, instead of pouring and brushing, the material is treated in a winnowing machine, similar to that used for separating chaff from wheat.

Although the best grade of sand, produced by the above complicated treatment, may be as high as 85 per cent. pure, its quantitative proportion is small as compared with the second and other inferior grades, and there is always considerable loss of monazite in the final tailings. It is impossible to conduct this washing process without loss in monazite, and equally impossible to make a *perfect* separation of the garnet, rutile, titanic iron ore, etc., even in the best grades.

But very few regular mining operations are carried on in the region. As a rule each farmer mines his own monazite deposit and sells the product to local buyers, often at some country store in exchange for merchandise.

At the present time the monazite in the stream beds has been practically exhausted, with few exceptions, and the majority of the washings are in the gravel deposits of the adjoining bottoms. These deposits are mined by sinking pits, about 8 feet square to the bed rock, and raising the gravel by hand labor to a sluice-box at the mouth of the pit. The overlay is thrown away, excepting in cases where it contains any sandy or gritty material, when it is also washed. The pits are carried forwards in parallel lines, separated by narrow belts of tailings dumps, as shown by the accompanying illustrations taken from the Lattimore mine, three miles N.E. of Shelby, Cleveland County.

It has been shown that the monazite occurs as an accessory constituent of the country rock, and that the latter is decomposed to considerable depths, sometimes

as much as 100 feet. On account of the minute percentage of monazite in the mother rock, it is usually impracticable to economically work the same in place, by such a process of hydraulicking and sluicing for instance.

However, hillside mining of surface soil to depths of 4 to 6 feet, has been carried on in certain localities with apparent success. The material is transported in wheelbarrows to washing boxes situated below a water race, as shown in the accompanying illustration from the Pfeifer mine, three miles east of Shelby. The resulting monazite product is very clean, and the cost of digging and washing the soil is even less, at times, than that in working the lowland gravels.

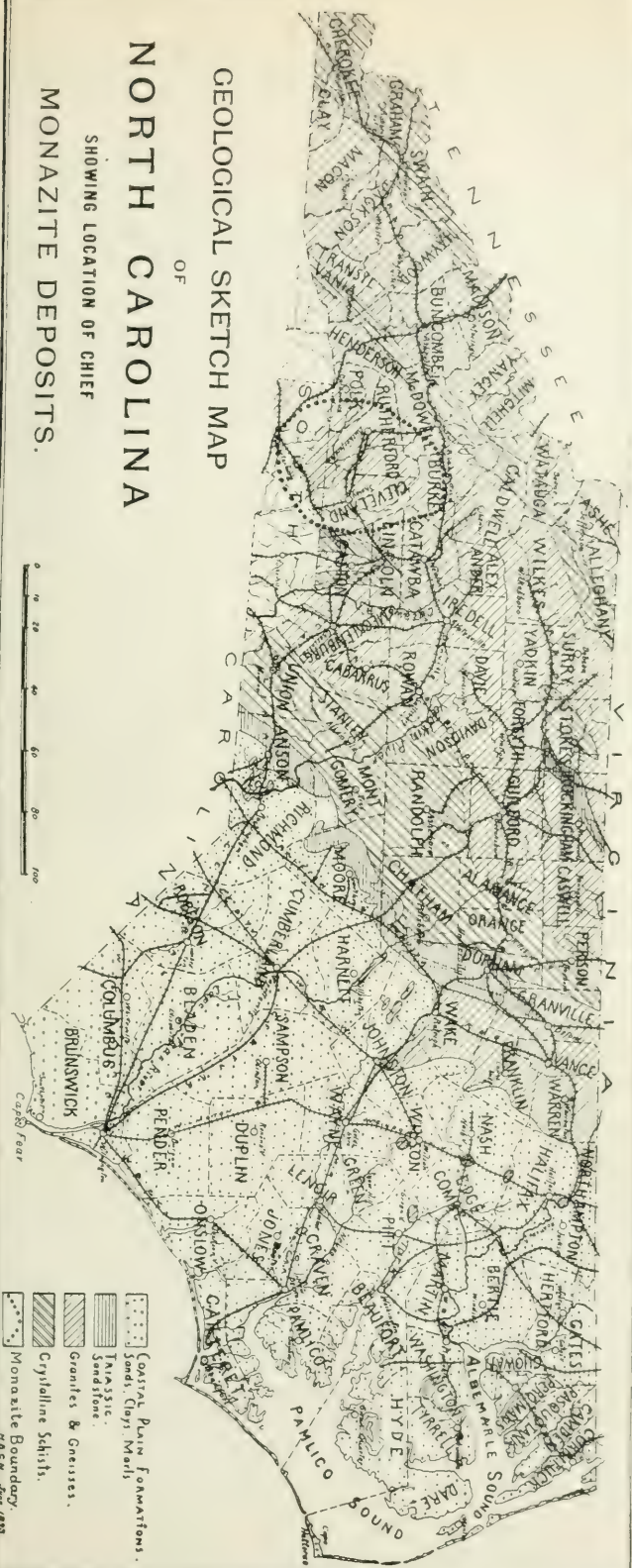
The value of monazite is more or less dependent on the percentage of thorium which it contains, as this is the element of greatest value in the manufacture of the incandescent mantles. As the percentage of thorium varies in different sands, the value of the sand consequently varies in a measure also. There is no method of determining even the probable percentage of thorium, excepting by careful chemical analysis. Some monazite contains practically no thorium. The best Carolina sand runs from 2 to as high as 6 per cent. thorium.

The price of Carolina monazite has varied from 25 cents per pound in 1887, to as low as 3 cents for inferior grades and 6 to 10 cents for the best grades in 1894 and 1895.

The production and value of Carolina sand for the past three years was as follows:

| 1893 | | 1894 | | 1895 | |
|-------------|---------|---------|----------|-----------|-----------|
| Amount | Value | Amount | Value | Amount | Value |
| 130,000 lbs | \$7,600 | 546,855 | \$36,194 | 1,573,000 | \$137,150 |

GEOLOGICAL SKETCH MAP OF NORTH CAROLINA SHOWING LOCATION OF CHIEF MONAZITE DEPOSITS.



- Coastal Plain Formations.
- Tertiary.
- Sandstone.
- Granites & Gneisses.
- Crystalline Schists.
- Monazite Boundary.

WORKABLE MONAZITE AREA IN NORTH CAROLINA.



WASHING GRAVEL AND SAND IN STREAM BEDS FOR MONAZITE, LATTIMORE MINE.

THIS VALLEY, 3 MILES N. E. OF SHELBY, IS 400 TO 500 YARDS WIDE AND ITS UNDERLYING GRAVEL ESTIMATED YIELDS MONAZITE



MINING AND WASHING GRAVEL BEDS FOR MONAZITE, LATIMORE MINE.



425

DIGGING AND WASHING HILL-SIDE SOIL FOR MONAZITE.

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[CONTRIBUTIONS TO THE CHEMISTRY OF ZIRCONIUM. No. 5.]

A STUDY OF THE ZIRCONATES.

BY F. P. VENABLE AND THOMAS CLARKE.

This class of compounds of zirconium has received but little attention from chemists. The chief investigator in the past who has worked in this field was Hiortdahl.¹ Of recent years several papers by L. Ouvrard² have appeared. The accounts given in the various text books of these zirconates are based upon the work of Hiortdahl or upon such abstracts of it as were to be found in the *Jahresberichte*, or in such dictionaries as that of Watts. This is unfortunate, as to the best of our knowledge the work of Hiortdahl itself is in some respects inaccurate and erroneous, and the abstracts of it are misleading. Before giving an account of our own experiments, it may be well to gather together the statements regarding these bodies as given by Watts and in the original article of Hiortdahl.

Watts says that the compounds of zirconia with the stronger bases are obtained by precipitating a zirconium salt with potash or soda, also by igniting zirconia with an alkaline hydroxide. "Zirconate of potassium thus obtained, dissolves completely in water." His first mode of preparing the zirconates is very questionable; the last statement is not true. He then goes on and describes zirconates of sodium, calcium and magnesium, as described by Hiortdahl. The details of Hiortdahl's analyses.

¹ *Ann. Chem. Pharm.*, 137, 34, 236.

² *Compt. Rend.*, 112, 144-46, and 113, 1021-22.

etc., will show on what an imperfect basis the knowledge of the constitution of these bodies rests. Hiortdahl states that he secured direct union only by ignition with alkaline carbonates. His attempts with the volatile chlorides failed. On heating zirconia with sodium carbonate one equivalent of carbon dioxide was driven out, and it is on the loss of carbon dioxide upon ignition that his figures for the composition of the resulting products are largely based. On heating equivalent amounts of zirconia and sodium carbonate a crystalline mass was obtained, which slowly absorbed moisture from the air. On treating this with water no decomposition was noted at first, but soon the water became alkaline and zirconia separated. This was taken as proof that the zirconia was decomposed by the water. In the experiment 0.3910 gram zirconia heated with 0.3130 gram sodium carbonate to a dark redness for nine hours lost 0.1310 gram carbon dioxide, and on treatment with water 0.3871 gram "zirconia," or 99.03 per cent. was left. If an excess of sodium carbonate is used can one drive out two equivalents of carbon dioxide. A little further down he notes that the "Gewichtsverlust zugleich von der Temperatur und der Dauer des Glühens abhängt." These are the determinations from which formulas for the zirconates are worked out.

It is scarcely necessary to say that for purposes of calculation these figures are entirely worthless. The loss of carbon dioxide is due to a partial formation of hydroxide as well as to a combination with zirconia. The fused mass of sodium carbonate, hydroxide, zirconate and unchanged zirconia will of course prove hygroscopic, and water will wash away all except the last two mentioned. We have failed to get any positive evidence that a zirconate formed by fusion was decomposed by water or was appreciably soluble in it.

In his second paper, Hiortdahl treats the fused mass of zirconia and sodium carbonate with water acidified with hydrochloric acid and analyzes the residue, finding in it:

ZrO_2 , 78.54 per cent.; Na_2O , 5.40 per cent.; and H_2O , 16.89 per cent., corresponding to $\text{Na}_2\text{O} \cdot 8\text{ZrO}_2$. He gets zirconate of magnesium and calcium by fusing zirconia and silica with magnesium chloride and calcium chloride respectively.

Ouvrard obtained his zirconates by fusions with the chlorides, also using those of lithium, calcium, strontium and barium. In some cases, instead of using zirconia, he took powdered zircons, obtaining silico-zirconates.

In our own experiments the following methods of forming the zirconates were tried:

I. Fusing in boron trioxide the zirconia and the basic oxide (Ebelmen).

II. Fusing zirconia with alkaline carbonates, (Hiortdahl).

III. Fusing zirconia with alkaline hydroxides.

IV. Fusing zirconia with alkaline or earthy chlorides (Hiortdahl).

V. Precipitation of solutions of zirconium salts with alkaline hydroxides (Watts).

VI. Dissolving zirconium hydroxide in strong solutions of sodium or potassium hydroxide and precipitation by dilution or by neutralization with an acid.

I. FUSION WITH BORON TRIOXIDE.

This method, made use of by Ebelmen in the case of other oxides, is useless in the case of zirconia, because this oxide is not taken up by the boron trioxide, and so does not come in contact with the other oxide. The melt of boron trioxide was kept at a high temperature for a number of hours without any appreciable solvent action upon the zirconia, added in small portions.

II. FUSION OF ZIRCONIA WITH ALKALINE CARBONATES.

The purified zirconia used had been dried at the temperature of the steam bath and therefore was not in the inactive condition brought about by igniting it at a very

high temperature. This was the case in the subsequent experiments also.

It is by fusion with sodium carbonate that Hiortdahl claimed to have prepared his zirconates. Ouyvard seems to have gotten little besides crystals of zirconia. Very little action could be seen in the experiments described below. The zirconia sank to the bottom of the fused mass and remained without apparent change for hours. Varying the time of heating did not seem to have much effect upon the results.

After the fused mass had cooled it was leached with successive portions of water until no alkali could be detected. The wash water contained no zirconium. As the mass left will absorb carbon dioxide, it was dried as rapidly as possible at about 150° to constant weight. Dilute hydrochloric acid was used to separate the zirconate formed from the unchanged zirconia. As this zirconia was now in the ignited and even crystalline form, it was concluded that it was insoluble in the dilute acid. The zirconia in the solution was precipitated as hydroxide and determined as oxide, and the alkali determined in the filtrate. Two grams of zirconia were used in each case and a large excess of the carbonate. The amount of unattacked zirconia ranged from ninety-three to ninety-nine per cent., showing thus very little action after many hours of fusion. In some cases, therefore, the amount of supposed zirconate obtained was too small for reliable analysis.

I. WITH SODIUM CARBONATE.

Three experiments with sodium carbonate were carried to completion.

1. Two grams zirconia and eight grams sodium carbonate were fused three hours. Amount of residue after leaching, soluble in dilute hydrochloric acid, 0.1588 gram, or eight per cent. In this ZrO_2 75.70 per cent.; Na_2O =24.30.

2. Two grams zirconia fused with sixteen grams sodium carbonate for four hours. Amount of residue soluble in hydrochloric acid, 0.3042 grams. Percentages: ZrO_2 , 74.18; Na_2O , 25.81. These correspond fairly with $(\text{ZrO}_2)_3(\text{Na}_2\text{O})_2$.

3. Two grams zirconia fused with sixteen grams sodium carbonate for eight hours. Amount soluble in dilute hydrochloric acid 0.1220 gram, or six per cent. Percentages: ZrO_2 , 58.16; Na_2O , 41.84.

II. WITH POTASSIUM CARBONATE.

When potassium carbonate was used the action was so slight that it was not possible to get enough for analysis. In one case, after heating for ten hours, the amount soluble was just one-half per cent. This accords with the observation of Ouvrard.

Of course it is possible that the leaching with water had a partially decomposing effect upon the zirconates. Very little could be justly concluded, however, from experiments in which there was so little action, therefore the effort at forming the zirconates by fusion with the carbonates was abandoned.

III. FUSION OF ZIRCONIA WITH HYDROXIDES.

1. *Fusion with sodium hydroxide.*

Here considerable action was noticed. The fusions were made in a silver dish. The heating was kept up until the mass became semi-solid. The treatment of the fused mass and the analysis were carried out as before. No zirconium was detected in the wash water.

1. Two grams zirconia fused with eight grams sodium hydroxide. Total amount dissolved, 1.1855 grams. An analysis, reduced to dry basis, gave ZrO_2 , 92.29, and Na_2O , 7.65.

2. Same amount taken as in experiment 1. Total amount dissolved 0.7655 gram, containing ZrO_2 , 93.19, and Na_2O , 6.22.

3. Two grams zirconia and sixteen grams sodium hydroxide. Amount dissolved 0.8004 gram, containing ZrO_2 , 92.57, and Na_2O , 7.38.

4. Two grams zirconia were fused with eight grams of sodium dioxide, instead of the hydroxide. Amount dissolved 0.7074 gram, and this contained 91.21 per cent. ZrO_2 .

$\text{Na}_2\text{O} \cdot (\text{ZrO}_2)_6$ contains ZrO_2 , 29.30; and NaF_2 , 7.80.

$\text{Na}_2\text{O} \cdot (\text{ZrO}_2)_7$ contains ZrO_2 , 93.29; and Na_2O , 6.79.

2. *Fusion with potassium hydroxide.*

These were carried out in a manner similar to those with sodium hydroxide and the action seemed to be about the same. In each experiment two grams of zirconia were taken and fused with sixteen grams of potassium hydroxide.

1. Dissolved by hydrochloric acid 0.8850 gram which contained 79.63 per cent. ZrO_2 ,

2. Dissolved 1.5241 grams which contained ZrO_2 , 82.98; K_2O , 17.00.

3. Dissolved 1.2078 grams which contained ZrO_2 , 78.59; K_2O , 21.40.

4. Dissolved 0.9297 gram which contained ZrO_2 , 85.51; K_2O , 14.49.

In analyzing these alkaline zirconates the water present was not determined. The moist powder was treated with hydrochloric acid, the insoluble portion caught upon a filter, and the zirconia and alkali determined in the filtrate and the results calculated upon a dry basis. If the analysis given by Hiortdahl is calculated upon a dry basis, it gives for ZrO_2 93.51, and Na_2O , 6.49, or very nearly the the numbers gotten in experiment 2 in the fusions with sodium hydroxide.

It is difficult to interpret the results of these fusions with the alkaline carbonates and hydroxides. The fusions do not yield the same definite results each time, and indeed it cannot be claimed from the analyses that definite zirconates have been prepared. Some allowance must be

made for the imperfect method of separation of the zirconate from the unchanged zirconia, some of the former being taken up by prolonged digestion with hydrochloric acid. There is a marked tendency, however, toward the formation of certain zirconates under approximately the same conditions. Two of the experiments with sodium carbonate give results fairly in accordance with the formula $(\text{Na}_2\text{O})_2(\text{ZrO}_2)_3$. In the fusion with sodium hydroxide the results range from $(\text{Na}_2\text{O})_2(\text{ZrO}_2)_3$ [$\text{ZrO}_2 = 90.76$; $\text{Na}_2\text{O} = 9.24$], to $(\text{Na}_2\text{O})_2(\text{ZrO}_2)_4$ [$\text{ZrO}_2 = 94.08$; $\text{Na}_2\text{O} = 5.92$], and it is with these that the analysis of Hiortdahl agrees, though his was a fusion with sodium carbonate. Why there should be this difference is not clear. The tendency is manifestly toward the formation of what may be called the polyzirconates, having a considerable excess of zirconic acid. In the case of potassium the carbonate failed to give a compound. The hydroxide gives results ranging from $(\text{K}_2\text{O})_2(\text{ZrO}_2)_3$ [$\text{ZrO}_2 = 79.57$; $\text{K}_2\text{O} = 20.43$], to $(\text{ZrO}_2)_3(\text{K}_2\text{O})_4$ [$\text{ZrO}_2 = 86.74$; $\text{K}_2\text{O} = 13.26$]; again polyzirconates with excess of zirconia.

Other fusions were carried out with sodium and potassium hydroxides, and the resulting masses were leached with dilute acetic acid, a solvent which had to be used in leaching away the alkaline earths in the subsequent experiments. In the case of sodium the leaching removed practically all of the alkali. In the case of potassium a substance containing ZrO_2 , 78.59 per cent., and K_2O , 21.41 per cent. was left. This nearly corresponds to the formula $\text{K}_2\text{O} \cdot \text{ZrO}_2$. It is almost exactly the result gotten in one of the previous experiments.

3. Lithium gave no zirconate when the carbonate was used for the fusion. With the hydroxide it gave the following results:

Two grams ZrO_2 were fused with excess of lithium hydroxide, leached with dilute acetic acid and with water. This gave on analysis ZrO_2 , 89.11 per cent.; Li_2O , 10.99

per cent. Percentage of ZrO_2 calculated for $\text{Li}_2\text{O} \cdot 2\text{ZrO}_2$ is 89.13.

4. Calcium oxide was also heated for a number of hours with zirconia and gave the following results:

| | I. | II. | Calculated for $\text{CaO} \cdot \text{ZrO}_2$. |
|----------------------|-------|-------|---|
| ZrO_2 | 70.11 | 70.83 | 68.54 |
| CaO | 29.88 | 29.14 | 31.16 |

These residues, after treatment with dilute acetic acid and water, were crystalline.

5. Barium hydroxide differs from that of calcium in that it fuses readily and thus affords much better opportunity for reaction. The fusion gave abundant evidence of action. The excess of hydroxide was washed out with water. The carbonate present was dissolved away with dilute acetic acid until there was no more barium in the wash water. No zirconia was found in any of these washings. Towards the latter part of the washing the solid particles settled out with great difficulty. The residue was analyzed with the following result:

| | Found. | Calculated for $\text{BaO} \cdot \text{ZrO}_2$. |
|----------------------|--------|---|
| ZrO_2 | 55.51 | 55.95 |
| BaO | 44.49 | 44.05 |

This is a grayish white powder, very fine and easily soluble in hydrochloric acid. Practically all of the zirconia was taken up, leaving little undissolved by the hydrochloric acid.

6. Strontium oxide was prepared by ignition of the nitrate and heated in the same way as the calcium oxide. This mass was pinkish white, probably from slight impurities, and was completely soluble in dilute hydrochloric acid. On analysis the following results were obtained:

| | Found. | Calculated for $\text{SrO} \cdot \text{ZrO}_2$ |
|----------------------|--------|---|
| ZrO_2 | 54.22 | 54.55 |
| SrO | 45.77 | 45.45 |

7. The magnesia (eight grams) and zirconia (two grams)

was heated together for about four hours and then treated in the same manner as the calcium fusion, *i.e.*, first leached with dilute acetic acid and then washed with water until free from magnesia. The residue gave evidence of being crystalline.

| | Found | Calculated for $\text{MgO} \cdot \text{ZrO}_2$ |
|----------------------|-------|---|
| ZrO_2 | 76.28 | 75.30 |
| MgO | 23.70 | 24.70 |

IV. FUSION OF ZIRCONIA WITH CHLORIDES.

This method was used by Hiortdahl in preparing the zirconates of magnesium and calcium, and by Ouvrard for the same, and also for strontium, barium and lithium. According to the latter they all gave zirconates of the form M_2ZrO_3 .

1. *Fusion with sodium chloride.*

There appeared to be very little action. The fusion was washed with water until free from chlorine. It was then treated as in the case of the carbonates. When two grams of zirconia were fused with sixteen grams of sodium chloride, it was found that less than two per cent. had been dissolved. In a second experiment, after heating six hours, the amount dissolved was less than two-tenths of a per cent.

2. *Fusion with potassium chloride.*

No action was observable. When two grams of zirconia were heated a number of hours with an excess of potassium chloride and the mass then treated as above, only three-tenths of a gram had been acted upon. There seemed to be even less action in the case of lithium chloride at the temperature attainable by means of an ordinary water-blast lamp.

3. *Fusion with alkaline earths.*

Two attempts were made to prepare magnesium zirconate by fusing zirconia with magnesium chloride and ammonium chloride. It was not possible to prevent

decomposition of the magnesium chloride. There seemed to be some action, but much difficulty was experienced in separating the products. The method described by Ouvrard gave evidences of zirconium in the washings.

In the case of fusions with calcium chloride no action could be observed. Two experiments were made, following closely the directions of Ouvrard, except as to temperature possibly, as to which no exact directions were given. A water-blast lamp was used for several hours. After leaching and washing, the mass left behind gave no zirconium to hydrochloric acid.

Our experiments with the chlorides have led us to believe that there is little or no action between zirconia and the chlorides of the alkalis or alkaline earths except where these chlorides are decomposed by the heat and oxides formed. Any action noticed is to be attributed to the oxides.

V. PRECIPITATION FROM THE SOLUTION OF A ZIRCONIUM SALT BY MEANS OF AN ALKALINE HYDROXIDE.

Watts speaks of this method but no experiments are recorded. It seemed to us upon examination of the question that very little evidence as to the existence of the zirconates or their properties could be drawn from such a method of preparation as this. It has been repeatedly observed that the precipitate formed by means of ammonium hydroxide is extremely hard to wash free from ammonia. After a very large number of washings, however, it is practically free from ammonia. The same is true of sodium and potassium hydroxides. Is it to be inferred that a definite zirconate is precipitated? At what point shall the washing be stopped, for manifestly some washing is necessary? Equally, it cannot be decided because of this loss of alkali by prolonged washing, that we have a decomposition of the zirconate caused by the action of the water. It, therefore, seems to be quite useless to make analyses of the precipitates gotten with different degrees

of washing; especially as somewhat similar experiments were carried out under the next heading.

VI. THE SOLUTION OF ZIRCONIUM HYDROXIDE IN CAUSTIC ALKALI.

It was found that zirconium hydroxide was perceptibly soluble in solutions of potassium and sodium hydroxide. Experiments were first made with a view of determining the extent of this solubility. Solutions of the two alkalis were made up of different strengths, an excess of zirconium hydroxide added, and the solution then boiled. After cooling, a measured quantity of the solution was drawn off and the amount of zirconia present determined.

| | | | | | | | | | |
|--|---|---|---|---|---|---|---|---|-----------|
| A 50 per cent solution potassium hydroxide dissolved per cc. 0.00233 gm. | | | | | | | | | |
| 33 | " | " | " | " | " | " | " | " | 0.00097 " |
| 25 | " | " | " | " | " | " | " | " | 0.00075 " |
| 12 | " | " | " | " | " | " | " | " | 0.00009 " |

In the case of sodium hydroxide there seemed to be a stronger solvent action.

| | | | | | | | | | |
|--|---|---|---|---|---|---|---|---|-----------|
| A 33 per cent solution dissolves per cc. 0.00245 gram. | | | | | | | | | |
| 25 | " | " | " | " | " | " | " | " | 0.0012 .. |
| 12 | " | " | " | " | " | " | " | " | 0.0005 " |

If a concentrated solution of alkali, saturated with zirconium hydroxide, is diluted, a portion of the zirconium will be precipitated. Neutralization with acid will also cause a precipitation of the zirconium. In both cases alkali is retained by the precipitate in spite of washing. Analyses were made of some of these precipitates after very thorough washing (in no case was less than a liter of water used.) The results in four experiments were sufficient to show that these precipitates were practically zirconium hydroxides with a varying percentage of alkali, this percentage ranging from 1.15 to 3.94. It is possible to assume that zirconates were formed and then decomposed by the action of water during the washing, but it seems more probable that this is, as is true in the

case of so many hydroxides precipitated by alkaline hydroxides, merely a stubborn retention of alkali. Assuming that the strong alkaline solutions held zirconates in solution, attempts were next made to prepare other zirconates by precipitation from them.

The addition of solutions of various salts gave small precipitates which seemed to be formed mainly because of the dilution of the alkaline hydroxide and to consist almost entirely of zirconium hydroxide. It was necessary, therefore, to use strongly alkaline solutions of the compounds of the elements to be experimented with. This greatly diminished the choice of compounds. Concentrated solutions of aluminum and zinc hydroxides in potassium hydroxide gave precipitates but they were in too small amounts for reliable analyses to be made.

Summing up the results of the experiments performed, it is clear that the method yielding the best results for the preparation of the zirconates is fusion of gently dried zirconia with hydroxides or prolonged heating with the oxides. In the case of the alkaline earths this yields zirconates containing one equivalent of each oxide, $\text{CaO} \cdot \text{ZrO}_2$, etc. The same is true of the magnesium compound. For lithium the compound obtained was LiOZrO_2 . For the alkalis it seemed to be possible to obtain only zirconates having a largely preponderating proportion of zirconia. There seems to be a tendency toward the formation of distinct compounds under certain conditions. These polyzirconates, and the lithium compound also, may be decomposition products due to the action of the water used in leaching. No other mode of separation from the products of the fusion could be devised by us, however. If they are produced by the decomposing and solvent action of water, it is a little strange that a point should be reached beyond which the leaching extracted no more alkali, and that this point varied with changed conditions. This is not the case where zirconium hydroxide has been precipitated by an alkali.

DOUBLE ZIRCONATES.

Two attempts at the formation of double zirconates were made.

1. Potassium calcium zirconate.

About two grams each of zirconia, potassium hydroxide and lime were heated together for about four hours. There was evidence of considerable action. The mass was treated with dilute acetic acid and thoroughly washed. Then on treatment with dilute hydrochloric acid nearly the whole residue went into solution. The analysis gave ZrO_2 , 67.21 per cent.; CaO , 31.06; K_2O , 1.11. This is a calcium zirconate, $(\text{CaO}.\text{ZrO}_2)$, with a small part of the CaO substituted by K_2O .

2. Potassium aluminum zirconate.

Two grams of zirconia were fused for eight hours with two grams potassium hydroxide and three grams of alumina. The mass was washed with dilute acetic acid until no more alumina was dissolved. The residue was treated with dilute hydrochloric acid and the insoluble portion removed by filtration. The analysis gave ZrO_2 , 72.38 per cent; Al_2O_3 , 7.66; K_2O , 20.00. These experiments indicate the possible existence of double zirconates, and when time permits this point will be further examined.

RIVER ADJUSTMENTS IN NORTH CAROLINA.

W. J. WEAVER.

NOTE.—In presenting this paper I beg to acknowledge my indebtedness to the lectures of Prof. Collier Cobb, and to his work and that of Messrs. Chas. Baskerville, R. H. Mitchell and other members of the class engaged in advanced work in Physical geography; but the mode of presentation is my own and I alone am responsible for any short-comings it may have. As my paper was presented for the Kerr Prize in Geol-

ogy it has not even had the critical reading of the head of the department, and lack of funds prevents my presenting as many maps as were contained in the paper.

North Carolina is naturally divided in three sections: (1) The Eastern or Coastal plain; (2) The Piedmont Section, and, (3) The Western or Mountain District.

The coastal plain runs inland about 100 or 125 miles. "Its western boundry line runs from the western part of Warren through Franklin, Wake, Cumberland, Chatham, Moore, Montgomery, and Anson counties." The whole coastal plain belongs to the Quarternary system, with frequent expanse of the Eocene and Miocene of the Tertiary along the rivers and ravines. As we go inland the country rises about one foot per mile, but from North to South is almost level. Over the whole section the primitive rocks are covered with a deep stratum of earth, principally sand. Along the western border and river courses we find granite, slate, and other rocks sparingly distributed, but no rocks of any kind can be found anywhere else in the region. The section is made up of beds of clay and sand with vast quantities of shell imbedded in them. The upland soil is mostly sandy loam which yields very good crops. There are vast areas of sand that will not yield anything but pines. In fact we know that this whole region has in recent geological time been raised above the sea level.¹

The Piedmont Section begins on the western edge of the coastal plain and runs west to the borders of the Blue Ridge. It is a rolling prairie in the east and gets rougher towards the west, including some small mountain ranges, the Brushy, Pilot, and King's Mountain. The mountain chains of the western part of the Piedmont belt run northeast and southwest; and as the rivers pass them they form rapids and falls that give excellent opportunity for manufacturers.

1. Handbook of North Carolina, 1885, published by Board of Agriculture.

Though you would expect a very rough hilly country on the West you do not find it so. The slope on the eastern side of the Blue Ridge is much steeper than that of the West. West of the Blue Ridge we have a very large valley bounded on the East by the Blue Ridge and on the West by the Great Smoky Mountains. This valley runs northeast and southwest between the two mountain chains and composes the mountainous districts of North Carolina.

This area has principally crystalline schists and gneisses with patches of conglomerates, sandstones, and shales and limestone. Both the Smokies on the West and the Blue Ridge on the East presents an anticlinal structure; the latter often having its monoclinial member absent. The area was in all probability once covered by an eastern extension of the Paleozoic rocks of East Tennessee, the sandstones of the western district being probably Cambrian (Chilhowee or Potsdam), the patches of limestone probably Silurian, and the grits and shales farther East possibly Carboniferous.¹ I assume that the folding that produced the Appalachian System was, as in Pennsylvania, rapid enough to deform the river systems. It gave rise to four great systems in North Carolina. The first we may call the Deep River syncline. It had its head in Chesterfield County, South Carolina, on the North Carolina line and ran northeast into Virginia. The second had its head in Caldwell County, North Carolina ran east of northeast and joined the first in Virginia. This one may be called the Dan River syncline. The third had its head in Catawba County, North Carolina, and ran south into South Carolina. This may be called the King's Mountain syncline. The fourth, which we may call the Asheville syncline was rather a canoe-shaped basin with a length of about 150 miles and a width of 20

1. Professor Collier Cobb's Lectures on General Critical Geology, 1893-94; see also Cobb's Map of North Carolina, 1887.

miles in Watauga county and 50 miles in Henderson. Its ends are in Virginia and Georgia, and it took a Northeast and Southwest course. It was probably a lake for a long time until it flowed over, most probably in Henderson county. We find evidences of shores in Transylvania county that were evidently made by a lake. These synclines and the rivers that occupied them may be seen on map (1) It can be seen from the map that the original drainage of western North Carolina was not as it now is. Yet the present rivers are in many cases in the original river beds. The original river of the Asheville syncline headed in the northwest with what is now New river, ran southwest and crossed near Boone into the head waters of Watauga river, ran along the head waters of Watauga, but in the opposite direction taken by the Watauga now, for a few miles and crossed into the head of what is now Linville river, ran down the stream for about 20 miles and crossed into Brush creek and then into Toe river. At this point Linville river now enters what is known as the gorge. This is a very deep valley that has been cut since the original drainage we are describing. The river that cut through this great plateau has captured the Linville river and led it through, but at the time we are describing this gorge did not exist and the natural outlet was through Brush creek as stated. The river continued down Toe river as far as the fork known as South Toe, and there it crossed the present gap known as the Toe river gap. Down Swannanoa to French Broad and up French Broad and out through Mud creek into South Carolina, thence to sea. The drainage on the southwest began with the Hiwassee river which has since been captured and inverted, and ran east or a little south of east to Valley river, up Valley river, across Red Marble Gap and into Nantehala river, down this to its junction with Tuckaseege river, thence up Tuckaseege and across what is now known as Road Gap, down Richland creek to Pigeon river, up Pigeon to the great bend and

thence across Hominy Gap and down Hominy into the French Broad, up French Broad and out through Mud creek into South Carolina. We have many of our rivers in the original river beds. The Hiwassee has been captured and inverted but it still occupies the old bed. The Nantehala and Tuckaseege still occupy their old beds though there has been considerable change, a part of the latter having been inverted.

We would expect to find in these inverted rivers evidence of it in their sluggish movement but we must remember that most of them have since their inversion been so much lowered that they are the roughest to be found. The Little Tennessee River has cut a gorge through the Great Smoky Mountains over four thousand feet deep and we could hardly expect a river to be slow and sluggish whose lower waters had been lowered so much. Likewise the French Broad from above Hot Springs is very rough owing to the same fact. On the northwest the New river was made by cutting into the syncline and leading a part of the original river out. In map D we see that it is about to cut into the syncline and capture a part of the original river. Its headwaters push forward into the syncline until it has captured the headwaters of the original river and inverted a small part of it. This inverted part having a greater fall will move the divide southwest by degrees; and this continues until it reaches the mountain ranges near Boone which on account of its structure marks its final divide. The next stream that cut into our original river was the Watauga. It cut through the Smokies from Tennessee and led off a portion, but did its best work in determining the divide for the other rivers. The strata not all being of the same hardness we can see why these captures went as far as they did and no farther. When New River was inverted it probably would have led out much more of the streams of the northern and middle portions of the basin but for the fact that there was a ledge of rock that outcropped

about the central part of Watauga county and ran entirely across the basin at that point. These rocks had no influence upon the streams until the streams had levelled the country down to them. Then they formed a natural divide and fixed definitely the headwaters of New River. The Watauga was probably captured by a westward flowing stream on the southwest of these and therefore could not capture any of the New River's headwaters. Further on the south of the Watauga and running parallel to it there is another outcrop of rocks which run across the basin and join the Blue Ridge at Grandfather's Mountain, thus fixing definitely the divide between Linville and Watauga rivers. From this divide the river which goes south is Linville, which runs in the channel occupied formerly by the original river. This channel has the highlands of the Blue Ridge on the south and east; and on the west there is a range of mountains which separate Linville and Toe River. Linville River now runs down this valley about twenty miles and then enters what is known as the gorge. The original river formerly passed over and went down Brush Creek, Linville gorge not having been cut at that time, to Toe and down Toe as far as where South Toe enters. The Linville gradually gnawed its way back through a vast plateau and tapped the original river, thus leading off a few miles of it. We will also note that Linville is the only river that captured a stream from this basin and led it out to the east, all the rest have been captured and led off to the west through the Great Smokies.

The next capture was that of the headwaters of the Toe by the Nolichucky. This led all the North Fork of the original river out except the Swannanoa which still retains its old position. As the Nolichucky cuts through the Smoky Mountains it gradually lowers its channel and lowers the whole of the river. As the Nolichucky cuts its way back it furnishes a shorter route to the lowlands and being shorter it has a more rapid current which cuts

its channel faster and the divide migrates eastward until it is finally permanently located at Toe River gap, all the waters of the northwest having been captured by westward flowing streams. The next capture I shall take up belongs to the southwest tributary of the original river. The Hiwassee originally formed the headwaters of the river that drained the southern end of the Asheville syncline and led its waters up to the French Broad and thence out by that river. It is almost if not quite impossible to determine which of these captures took place first and in what order the others followed, but I am inclined to think that the rivers of the northeast were captured pretty much in the order that I have treated them, i. e., the headwaters (New River) were captured first, then a new stream cut in and took another deal off the head and so on down; in the southwest it is most probable that they did take this order. Considering the amount of erosion that the Little Tennessee has done I think that that stream was the first one to cut through and make a capture, thus draining all the basin west of the Balsam Mountains. Later the Hiwassee was captured and inverted and now runs out the southwest end of the basin. We can see by comparing the sketch of the original drainage with the map of to-day that the capture would turn a large volume of water through the Little Tennessee's gorge and thus help to sink it very rapidly. This is most probably what happened. As evidence of capture and inversion in the Little Tennessee River we have several rivers coming into it like the barbs on an arrow; i. e. they show their former tendency to run the other way. The Hiwassee also has several branches coming in in that manner, as the Nattely River and Shoal Creek. In map (I) we can see the river system of the Asheville syncline as it originally was. We see the little Tennessee and the river that captures the Hiwassee just cutting through the Great Smoky Mountains and looking in upon their prey. They are moving their respective divides to the

east and this continues until the divides have moved to their present position, and by this time the Little Tennessee has captured and inverted all the waters west of the Balsam Mountains and the divide has moved to Road Gap where it stops on account of the rocks that outcrop here. The Hiwassee is gradually overcome and captured in a similar manner. This only leaves Pigeon in its original position and running over what we now call Hominy Gap to the French Broad, and on the west we see the river that is to capture it cutting through the Smokies and gradually capturing its headwaters until they are finally all captured and led out through the Smokies. The New Found Mountains form a barrier between this river and Hominy Gap—the bed of the original stream is still the lowest gap in these Mountains.

The creek that flowed from the gap to French Broad is Hominy Creek and since the days of the readjustment it has recaptured two of its old tributaries; i. e. the two small branches that once ran to Pigeon River, now run into Hominy Creek and thence to French Broad*. All these waters that originally found their way to the sea through the upper French Broad valley would have made a large valley and such we find to-day. This stream has been cut into and captured by a stream from the west thus inverting the French Broad from its original course. The French Broad from the mouth of Swannanoa to Brevard, a distance of about forty miles, is a very smooth, sluggish river, so slow in its movements that one can but notice it and compare it to other mountain streams that usually go so rapidly. This is evidence of an inversion which has evidently taken place. From Asheville west, the French Broad is noted for its beauty, which consists in its rough, rugged course over rocks and through gorges, winding its way through the Great Smokies into the Appalachian River. There is very little fall in the French Broad between Brevard and Asheville while between Asheville

* National Geographic Magazine, vol. I, no. 4. By Bailey Willis.

and Paint Rock there is a great fall. At Asheville the altitude of the river is about 2100 feet while at Paint Rock it is 1264, thus giving a fall of 181 feet to the mile. The town of Brevard is lower than Asheville but both towns are above the river. However I believe that there would not be a difference of many feet in the altitude of the stream at the two places. We can see from map of the original drainage the French Broad as it ran south-east, with the river that is about to capture it cutting through the Smokies and having their divide just east of the Tennessee line. As in the other cases the divide has migrated east and the western river has captured and inverted the French Broad and led it out to the west. This finishes up the Asheville basin or syncline. Now let us look at the others. The next one I will take up is the old Dan River syncline which I have described above. It has had two changes. First it has been cut into by the Yadkin which has led about 50 miles of the Dan River headwaters to the sea through its channels and secondly it has had numerous readjustments through its headwaters and those of John's River, a tributary of the Catawba. In the drawing of the original drainage, map (I,) we can see the position of this syncline which originally extended into Virginia and met the Deep River syncline. In the drawing we see that the Yadkin is about to cut into the Dan and as soon as it cuts through it will take the waters to the sea because having a shorter distance to go it must have a greater fall and will hence take the Dan in preference to being captured. The Dan was thus turned from its course and led to the sea by the Yadkin. The present Dan River has a branch, Town Fork, that still follows the old bed. The headwaters of the Yadkin have extended themselves still further north and are now known as the Ararat River. We will now turn our attention to the captures made in the headwaters of the syncline; and this brings me to mention a fifth syncline in North Carolina which I had not noticed until after I had

begun my work on this paper. This syncline we may call the Round Knob syncline since Round Knob is in the syncline and near its head. It began in the west of McDowell and ran a little north of east through Burke and Iredell counties, and it is probable that it continued through Davidson, Randolph and Chatham and joined the Deep River syncline in the latter county although we have no definite evidence that it did. In Map (I) we can see the drainage of this syncline as well as the captures which its waters made on those of the Dan River Syncline. I was at first disposed to think that John's River had captured the branch of Yadkin called Yadkin and that later it had been retaken by the Yadkin, but upon examination I find that those branches near the head of the Yadkin come down from a high plateau and enter the Yadkin at right angles and I am convinced that the branch called Yadkin is merely conforming to the family trait and has never been captured by John's River. If we look at the branches now called John's River and Buffalo Creek we find they have the Yádkin family traits and they show they have been captured by John's River. As the Yadkin cut into and captured the Dan so the Round Knob Syncline has been cut into by the Yadkin and probably by the Catawba and its waters have not gone through the Deep River as they probably did at first. Third Creek is probably nearest the old channel that traversed Round Knob Syncline. The Catawba that cut into the Round Knob Syncline ran a little east of the King's Mountain Syncline originally and it was its tributaries that cut through the eastern side of this syncline and led its waters out. The River that originally occupied the syncline was most probably what we call West Fork of Catawba River. This joined the Catawba where it passes to South Carolina. We see from the original diagram that the tributaries of the Catawba are about to cut through the eastern border of the King's Mountain syncline and lead its waters to the Catawba, and as time

passed we see they kept pushing to the west until they have obtained the position they now occupy. Dutchman's Creek has cut through and branched in the syncline and now drains the whole of it. West Fork of the Catawba which was originally in the syncline has cut through the western border and now drains a large area northwest of the syncline; thus in time the rivers have changed their positions and have so greatly eroded the syncline that we only find traces of it left, such as Anderson and King's Mountain on the west, and on the east not even so much, however we can trace its borders between Dutchman's Creek and Catawba.

The Deep River syncline headed in Chesterfield county South Carolina, and ran northeast to Virginia where it joined the Dan River syncline. We can see its position by turning to the general drainage Map of North Carolina after the Permian uplift, (Map I). Its eastern border still makes the fall line in our rivers, but its western borders were not so well marked, and did not have so definite a boundary. In fact the eastern border was a wide spread of country gradually sloping into it. The eastern border may be seen by drawing a line from Cheraw, South Carolina, northeast passing about ten miles east of Raleigh and striking the Virginia line where Dan river enters North Carolina. Along this line is an outcrop of a number of the older rocks, principally granite. (Hand Book of North Carolina, 1886.) And a little west of this is the old Deep River bed. The river headed in South Carolina with Brown's Creek and ran northeast to the Pee Dee River which formed a part of its bed, up what is now Little river, across to Wolf's Creek, down this to Deep river and down Deep river to Haw river where it turned up what now is New Hope river and across to Store Creek, down this and up Knopf of Reed's Creek across to Tar river, up this, and to Fox Creek, over to Grassy Creek and down to the Dan river. At this time the coast line was only a few miles east of

this and the rivers such as Roanoke, Tar, Neuse, Cape Fear and others had not cut back to the syncline, however the distance to the sea was small and the fall was comparatively great and they were gradually cutting away. In drawing (Map 1) we can see how they cut this original deep river up and send their streams on westward for other adventures. The Great Pee Dee cut into the syncline near its head and led off Brown's Creek and inverted and led off Little river, then sent one of its streams on northwest and at last under the name of the Yadkin it cuts into the Dan River Syncline and captures a large part of its headwaters as we have described above. Cape Fear cuts into the syncline and leads off the part we now call New Hope and sends its branches on to help drain the territory northwest of the syncline (note the slowness of New Hope River). The Neuse cuts in and leads off a small portion as does the Roanoke, and thus helps the waters to find a shorter route to sea. At last this syncline leaves us this remnant of its former self as evidence of what it has been. The inverted creeks and rivers are yet at a loss to know what to do and so move along slowly, but by and by when they get accustomed to their new environment they will pick up their spirits and move along joyously as they did of old, and later generations will never know what a deal of trouble they have had. Their rate of flow is probably even now being accelerated by the lowering of the eastern border of the central plain.

REDUCTION OF CONCENTRATED SULPHURIC ACID BY COPPER.

BY CHARLES BASKERVILLE.

In a previous communication¹ the writer noted that copper was acted upon by concentrated sulphuric acid

¹This Journal, 17, 90.

(1.84 sp. gr.) not only at the ordinary temperatures of the air, 20° – 30° C., but at zero as well. Andrews¹ states that the assertion is incorrect and that it does not occur until the temperature 86° C. has been reached, or a point above the dissociation temperature of the concentrated sulphuric acid, 67° C. according to him. Andrews further says that the author's statements were based "not upon the demonstrations of the formation of sulphurous acid, but solely on the formation of copper sulphate," which, he says, occurs only "in consequence of the presence of the air." It is to be regretted that Dr. Andrews did not note carefully the statements of the author in his previous communication, as no reason whatever exists for any such conclusions, because it was distinctly stated that not only the copper as sulphate, but as sulphide was determined, as well as sulphurous acid, and moreover, that the experiments were carried out when the air had been replaced by a neutral gas, either hydrogen or carbon dioxide.

The author, although confident of the correctness of his former statement, carried out further experiments to correct the error, if committed or to establish, beyond question, the fact that concentrated sulphuric acid of 1.84 sp. gr. is reduced by copper below 86° C., the limit *positively* set by Dr. Andrews.

The fact that these experiments but confirmed the former statement of the author allows the incorporation of of the results in this paper.

As far back as 1838 the fact that copper is acted upon by concentrated sulphuric acid at ordinary temperatures, if sufficient time be given, was made known by Barruel². Calvert and Johnson,³ however, failed to obtain any action below 130° C., and considered that none took place.

¹ J. Am. Chem. Soc., 18, 253.

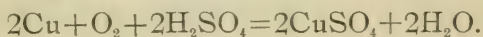
² J. de pharm., 20, 13, 1834.

³ J. Chem. Soc., 19, 438, 1866.

Pickering¹ however stated that "sulphuric acid attacks copper at all temperatures from 19° C., (and probably even still lower) upwards."

First Experiment.—Copper ribbon in strips, 1 x 3–4 cm., was submerged in concentrated sulphuric acid in a clean glass stoppered flask for a month. At the end of that time not only were there white crystals of anhydrous copper sulphate clinging to the sides of the containing vessel, but there was a very appreciable amount of brownish black cuprous sulphide and sulphur dioxide was easily detected by its strong odor when the vessel was opened.

Andrews² states "that in the presence of air sulphuric acid is attacked by copper at ordinary temperatures, but without reduction of the acid. The reaction must take place according to the equation,



Formerly the author³ stated that the presence of the oxygen of the air when it comes into contact with the copper in the acid has great influence on the reaction. Fifty years ago, Maumené⁴ proved that when a current of oxygen gas was passed through the boiling acid, the amount of insoluble residue, *v. g.*, cuprous sulphide, was diminished, that is, less than there would be formed if the experiment were carried out with a current of carbon dioxide. The copper must be directly opposed to the oxygen by only partial submersion or the bubbling of the air against or around the submerged copper; but the air in a confined space, not at all in contact with the copper, but separated by a thick layer of concentrated sulphuric acid, has little or no effect.

Yet grant that the oxygen of the air (volume of air

¹ *J. Chem. Soc.*, Trans., 1878, 113.

² *J. Am. Chem. Soc.*, 18, 252.

³ *Ibid* 17-912.

⁴ *Am. Chem. Phys.* 1846 [3], 18, 311.

about 200 cc.) confined in the flask, had been utilized in the formation of the copper sulphate produced. According to the formula given above; the oxygen would be absorbed and no corresponding amount of any other gas would be eliminated; consequently there should a greater external pressure at the close than at the beginning of the experiment. When the smoothly fitting glass stopper was removed, not only no extra external pressure was noticed, but in fact a pressure from within. This was evidently produced by the sulphur dioxide generated. The sulphur dioxide was swept out by a current of air through a dilute solution of potassium permanganate, which was quickly bleached. The presence of sulphur dioxide was further proven by the addition of barium chloride to the bleached potassium permanganate solution. Nor does the formula given above account for the cuprous sulphide which is always produced.

Second experiment.—Realizing the possibility of some organic matter or dust remaining in the flask, although it had been carefully cleansed, the first experiment was repeated with the greatest precaution to ensure the absence of dust. The flask was scoured with boiling concentrated pure sulphuric acid containing potassium bichromate and carefully cleansed with distilled water. The last traces of water were removed by four subsequent washings with the same kind of concentrated acid used throughout the experiments. The experiment was carried out in the same manner as the first, the same results being obtained.

A blank experiment was carried out at the same time. The flask was rendered dust free in the manner just mentioned and fifty cc. of the same acid allowed to remain in the flask for six months. At the end of that period not a trace of sulphur dioxide could be detected in the blank, therefore the sulphur dioxide produced when the copper was inserted could not be due to the reduction of the sulphuric acid by an extraneous substance, but

solely by the copper. The conclusion is that sulphuric acid is reduced by copper when air is present at the ordinary temperatures, 20° – 30° C.

Third experiment.—An ordinary Kjeldahl digesting flask was made dust free by the treatment noted above. 100 cc. sulphuric acid, 1.84 sp. gr., were placed therein and clean dry strips of copper-ribbon were completely submerged in the acid. Now air-free carbon dioxide was passed through the flask for three hours. The inlet tube was just dipped into the acid. The flask was then attached to a suction pump, with a sulphuric acid drying flask intervening to prevent a possible return flow of gas or air which might carry moisture or dust into the flask. The flask was exhausted of the carbon dioxide present for three hours at a pressure of 150 mm. It was then sealed with the blast lamp and placed aside in a darkened cupboard. Observations were made every few days to note any reaction taking place. Within two days it could be easily seen that copper sulphate had been formed and the liquid was somewhat clouded by very finely divided suspended cuprous sulphide. Continued observations extending over a period of seven weeks showed only an increase in the amounts of both of these substances. The temperature of the cupboard had at no time risen above 20° C., and was for most of the time much lower. The flask was then opened as any other sealed tube, and instead of an external pressure inward, which had been sufficient to heavily dent the tube in sealing, there was a strong internal pressure outward. The gas evolved was sulphur dioxide, easily detected by its strong odor and bleaching effect upon a dilute solution of potassium permanganate. The sulphuric acid produced by the oxidation of the sulphur dioxide by the permanganate was precipitated by barium chloride. All solutions and apparatus were proven to be free from traces of sulphur dioxide and sulphuric acid by a blank experiment.

Conclusion.—Concentrated sulphuric acid, 1.84 sp. gr.,

is reduced by copper when air is absent and at temperatures far below 86°C. , in fact at the ordinary atmospheric temperatures with the formation of copper sulphate and cuprous sulphide and the production of sulphur dioxide.

Finally.—Apparatus similar to that made use of by Andrews¹ with the modification of having three drying flasks containing concentrated sulphuric acid instead of one, and a Meyer absorption tube was substituted for a single small flask. These served merely as extra precautions against dust and insured an intimate mixing of the outgoing gases with permanganate. Within twelve hours the permanganate was bleached. Andrews' experiment lasted only fifteen minutes. The presence of the sulphur dioxide produced was easily detected by the odor when the apparatus was opened, and in the bleached permanganate solution by barium chloride. Copper sulphate and cuprous sulphide were formed.

Concentrated Sulphuric Acid is Acted upon by Copper at Zero.—Quantitative experiments were carried out by the author when the concentrated sulphuric acid in which the copper was submerged was practically at zero.² In stating the results, however, the author gave the temperature as " 0° – 10°C. " The flask containing the acid was buried in an ice-bath and the temperature of the liquid noted by a thermometer inserted through a rubber stopper. The apparatus was air-tight. A stream of hydrogen gas was continued through the apparatus in one experiment for six weeks and in another two months. On two occasions when the ice in the bath had melted in going over Sunday, the temperature rose to 10°C. The temperature could not possibly have remained that high for over twelve hours, which would have had small influence when the experiments lasted through a number of days. The temperature was reported 0° – 10°C. , how-

¹ J. Am. Chem. Soc., 18, 251.

² Ibid, 17, 908.

ever. Not only copper sulphate, but cuprous sulphide and sulphur dioxide had also formed. Copper, therefore, decomposes concentrated sulphuric acid (sp. gr. 1.84) practically at zero.

From my own experiments and from experiments performed with apparatus similar to that used by Andrews and under the same conditions, except in regard to the important element, time, which consideration is necessary for all chemical reactions, the author must adhere to his former statement.

THE USE OF THE PERIODIC LAW IN TEACHING.

Read before Am. Asso. Adv. Science, Buffalo, August, 1896.

Only a few years after the announcement of the periodic law, when as yet it had attracted little attention, Lothar Meyer pleaded for its introduction by teachers of Inorganic Chemistry so that something of the orderliness observed in organic chemistry might begin to appear in the study of the inorganic elements. A casual examination of the text-books of the period and indeed of those for a number of years afterwards, would show the great need of some such system. Again the great German teacher twenty years later appeared before the Chemical Society at Berlin and threw the weight of the experience of these added years and all his enthusiasm in favor of a thorough use of the periodic system in teaching inorganic chemistry.

Some system must be adopted in teaching this branch of chemistry or the task is hopeless. What will you use if the periodic system is rejected? Some have answered this by using the old families where the elements are arranged by chemical analogies. Even in these families

the influence of the periodic law is deeply felt as any one can see by examining into their condition a dozen years ago and comparing it with the present. Still they are a most unsatisfactory guide to the truths of the science. Some have maintained that the periodic system was little more than those same old groups or families. That shows great ignorance, and a most superficial study of the periodic system. It does include all that was of value in the old groups but much more besides.

The history of the atomic theory is repeated in that of the periodic system. It is now meeting something of the opposition and even denunciation which the atomic theory met with in the third and fourth decades after its announcement. The unexplained exceptions to it are being magnified and many are inclined to think them insuperable and to look with doubt upon the entire system, while some are ready to throw it overboard as rubbish past its usefulness.

I do not think that in these classes of opponents will be found any who have made patient and thorough study of this system. To me, the more I study it the more its interest and value grows and the more fascinating the search after the great truths which unquestionably lie within it and of which it yields glimpses even in its incomplete state. For the system is incomplete. It cannot well be otherwise until our knowledges of the science is broader and deeper. It will grow with and direct the growth.

But in its incomplete state it is amply sufficient to act as a most helpful guide to the study of inorganic chemistry. It introduces order and clearness where such were previously, in large measure, lacking. It saves much useless repetition and so brings about conciseness and brevity, a saving that appeals to both teacher and pupil. There are few earnest students who will not become enthused with the wonderful symmetry of the science and hence of all nature when this Natural System is unfold-

ed to them. I have had a student come to me with the confession that he had been able to see nothing of the attractive beauty of the science in his study of it until this system brought law and order into what had only been confusion to him before.

The brief time allotted to me gives opportunity only for an earnest plea in behalf of the introduction of the system and does not admit of an extended exposition of the application. An excellent guide along this line will be found in the lecture of Lothar Meyer before the German Chemical Society which I have already referred to but let me say that the only truly successful way of teaching this system is for the teacher to make a faithful study of it and its capabilities for himself. It is not the old system of families and it is not to be treated merely as affording a convenient classification. All that was true in those groups it retains but it further develops and in a measure explains them.

A few of the lines of usefulness of the system may be pointed out. First arbitrary distinctions, such as between metals and non-metals, which have given chemists so much trouble to define and maintain, can be done away with. The Berzelian division into electro-positive and negative elements is revived and fixed and enables one to account for the gradations between these elements.

The system gives a simple, easily remembered and applied arrangement of valence in the place of the confusion and difficulties of the old methods.

The full introduction of the periodic system means a consecutive study of the elements as allied bodies. This in a measure resembles the study of the hydrocarbons in organic chemistry. It is very valuable as giving a connected view of these bodies. The symmetry of chemistry is better shown and the student feels that he has a grasp of the whole, an intelligent comprehension of the properties chemical behavior and inter-relations of the elements which he can scarcely arrive at by the old way.

When it comes to studying the compounds they are studied connectedly. Thus the hydrides of all the elements, are examined, giving their relation to hydrogen; then the oxides and the influence of the negative and positive nature of the elements upon their relation to oxygen and hydrogen. Under the head of each acid (for the acid largely determines the general characteristics of the salt) the various salts are discussed. This gives a better understanding of the characteristics, saves repetition and tends to fix in the memory the compounds or classes. And so too the constant taking up of the elements in their groups and series fixes them in the mind.

I cannot give the system in detail. Study the periodic system and Meyer's lecture carefully and then laying aside prejudices and traditions go boldly to work. What I have stated about the advantages of the system may seem overdrawn. The statements are based upon an experience of three years and no one has the right to gainsay them until he has faithfully tried the system.



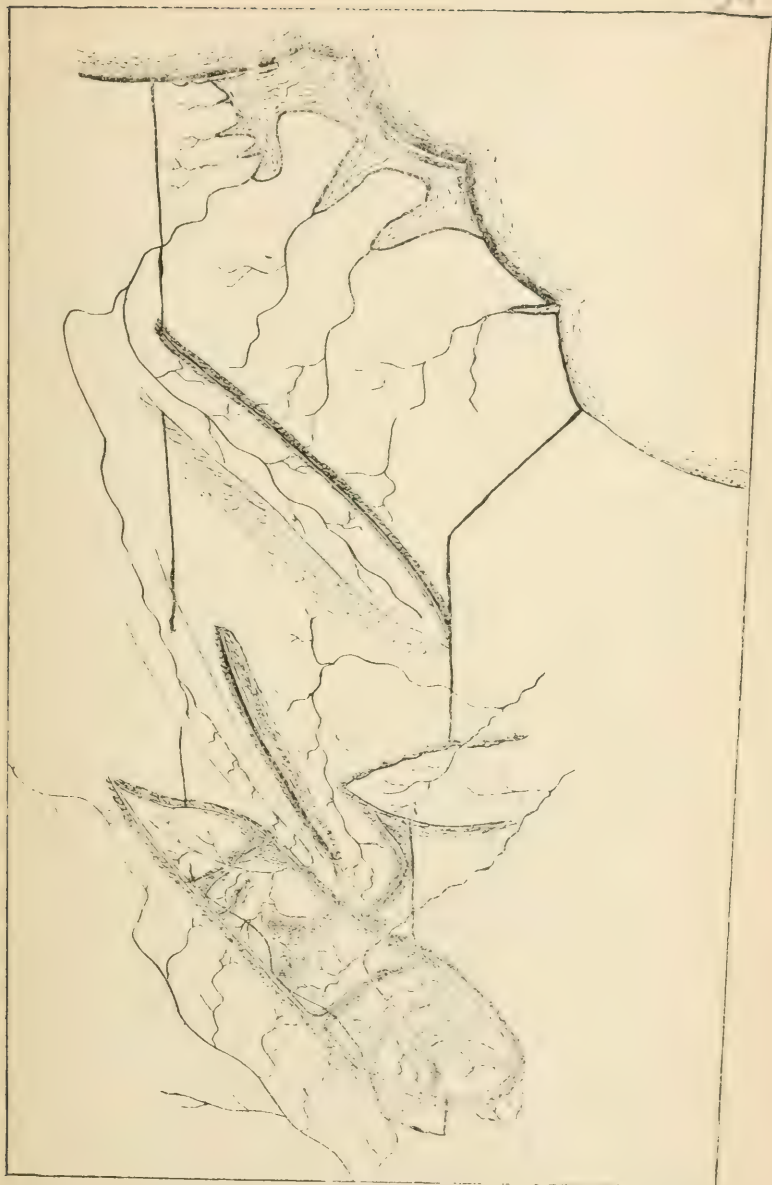


Fig. 1. Original Drainage.

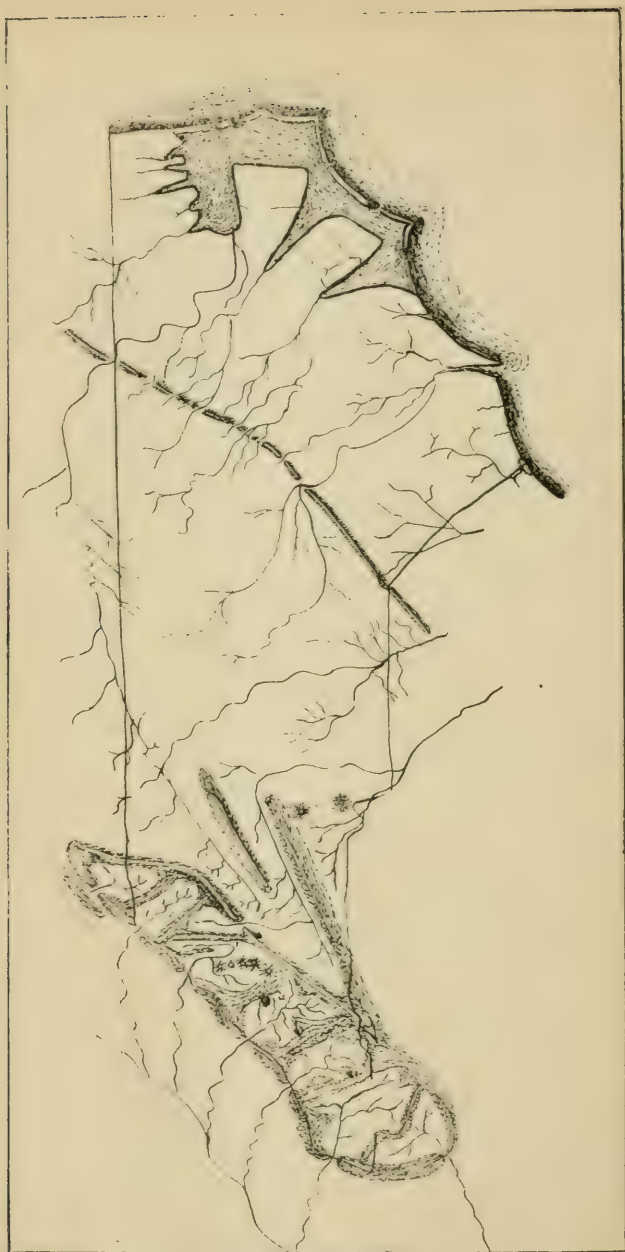


Fig. 2. Present Drainage.

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JOURNAL
OF THE
Elisha Mitchell Scientific Society.

THE PRESENT POSITION OF THE PERIODIC
SYSTEM.

The atomic theory, (first announced by Dalton in 1803) has for nearly a century formed the basis of Chemistry as a science. It is still the only plausible explanation of the vast array of facts gathered by chemists of all ages and forms the web and woof of all modern chemical theories. It has been the object of prolonged discussion and attack, but having withstood the storms of nearly a hundred years, its acceptance now is full and it has become so ingrained into the chemist's conception of his science that he looks upon it almost as one of his facts, a foundation stone of his building and seldom stops to realize that after all it is only an assumption, an hypothesis, a theory. To shake it would sadly disturb the fabric of his science.

A little more than twenty-five years ago with the announcement of the Periodic Law by Mendeléeff this atomic theory reached its highest development and gave its clearest promise of finally leading up to the solution of the true nature of matter. Like the original theory, this development of it received but tardy recognition but the sense of its importance has grown until it stands to-day the central fact of chemistry. Through it new zest has been given to research in fields from which it was thought the harvest had been gathered. It has given a new object to the chemist's work. It systematizes and arranges all the facts which he gathers. It gives a compactness and symmetry to his science unknown before. It brings a step nearer the realization of that dream of the

ages—the Unity of Matter. It may be said, with truth, that the Periodic System is the science of Chemistry itself. As such it must of necessity be incomplete. Through it we have been forced to realize how incomplete our science really is. In one sense, then, to study the present condition of the Periodic System would be to study that of chemistry. We will examine the question, however, from another and more-restricted point of view.

We may, in discussing the present position of the Periodic System, draw a distinction between certain points which are well established and others which are still under discussion or beyond our grasp at present.

First it is clear that the natural arrangement of the elements is in the ascending order of their atomic weights. This arrangement proved a failure when attempted by Gladstone because of imperfect atomic weights. In the hands of de Chancourtois, Newlands, Meyer and Mendeléeff it was developed and the singular relations between the elements, called periodic, were made apparent. This brings us to the second point, that when the elements are arranged in the order of their atomic weights they fall naturally into certain analogous groups and periods with a recurrence, or repetition, of properties at certain intervals. This leads up to the third point which we may acknowledge as fixed, namely that the properties of the elements are determined by and dependent upon the atomic weights. This was first stated by de Chancourtois, was proved independently and from a different standpoint by Hinrichs and was forced upon the attention of the world by the genius of Mendeléeff.

The points which still remain to be settled are very numerous. In the first place the number of the elements is unknown. Clarke, in the recent revision of his classic recalculations of the atomic weights, gives a list of 74. This leaves out of account all whose atomic weights are still very imperfectly determined or whose existence is still in doubt. Mendeléeff's table allows for the existence of

106 elements if a sub-period between hydrogen and lithium be granted. Meyer's table contains 79 spaces, or counting a similar hydrogen period 86 in all. If helium and its mysterious companion really have the two atomic weights assigned them, the assumption of this hydrogen group will become necessary. If Mendeléeff is right, then not more than three-fourths of the elements are at present known to us. The vacant space allowed by Meyer for new discoveries is much more reasonable and probably not much in excess of the demand of the near future.

Of the 74 recorded by Clarke less than one-half have the atomic weight determined with accuracy to the first decimal place. As Clarke says: "In most cases even the first decimal is uncertain, and in some instances whole units may be in doubt".

As the entire arrangement is dependent upon the atomic weights it is manifest that the doubt attaching to those in use seriously retards the development of the system. Some points of great interest must be left entirely in abeyance until data for accurate reasoning are at hand. The atomic weights of the first third of the elements are among the best known and this justifies the arrangement of those imperfectly determined. We would otherwise scarcely be justified in laying much stress upon the periodic arrangement.

The imperfectly known atomic weights makes it impossible to assign positions in the system to some of the rare earth elements and certain of those more recently discovered. If some of the atomic weights assigned those elements at present are even approximately correct then it seems to be impossible to give them their proper places in any of the more prominent tabular arrangements of the system.

This matter of the tabular arrangement of the elements is one which is very far from settled at present. Mendeléeff offers two arrangements, one in vertical, the other

in horizontal series. They differ widely in many important points. Some teachers make use of one, some of the other. The Germans and many teachers in England and America use Meyer's horizontal table. Many other tables have been proposed but they differ widely from those of the two great discoverers of the Periodic System and are generally intended to present and advocate some scheme as to the Genesis of the Elements or some other wild and questionable fancy.

I may be pardoned a brief reference to the table worked out by myself and suggested as an aid to teachers. It does not depart very far from the Mendeléeff horizontal table, but my own experience has proved it to be more easily taught and more quickly learned and hence very valuable for the teacher. It certainly brings out some facts which no other table presents, and when our knowledge is fuller it may aid in solving some of the puzzles now connected with the system.

It must be said that none of the systems are satisfactory, all are imperfect and incomplete and must remain so until our knowledge of the science is itself complete. Recent growth in the science has shown the insufficiency of the older arrangements. The discovery of argon and helium (and shall we add asterium?), the repeated determination of the atomic weights of iodine and tellurium and of the nearly twin elements cobalt and nickel showing them to be out of place in Mendeléeff and Meyer tables, have proved surprising reverses to the system after the brilliant successes of its earlier history. In the first table the existence of new elements had been predicted with an exact statement of their properties. These predictions had been marvellously fulfilled in the discovery of scandium, gallium and germanium. It was to be expected that future discoveries would only strengthen that which was already so strangely confirmed. But these new elements, argon and helium, were not predicted and refuse to be fitted into the system, as at present constructed, and are

altogether obstinate and refractory. In the minds of some the whole system seems overthrown. Let us have patience a little while until the light is clearer and both systems and these elements are better known and understood. As Winkler recently said before the German Chemical Society (Ber. d. Deutsch Chem. Ges. 30. 19) "Es erscheint nicht ausgeschlossen, dass die Entdeckung der beiden neuen Elemente Argon und Helium Anlass zum weiteren Ausbau, wenn nicht zur Umgestaltung, des periodischen Systems geben wird, wobei vielleicht auch gewisse, jetzt noch vorhandene Unsicherheiten und Widersprüche ihre Lösung finden werden."

It must not be forgotten that these tabulations began their existence with a serious blot upon them, an unsolved puzzle. From the very beginning no logically satisfactory position could be nor has yet been assigned to hydrogen. There have been sundry attempts at doing this, it is true, but they are not satisfactory and so the standard element, in some respects the most remarkable and important of them all, is without an abiding place in the home of its brethren. It would seem to be the play of Hamlet with Hamlet left out.

That these tabulations of Mendeléeff and Meyer are regarded as imperfect and unsatisfactory is shown by the large number of tables suggested within the last decade. Reynolds, Reed, Flavitzky, Livermore, Tchitcherine, Wendt, Wilde, Preyer, Deeley, Traube, Thomsen, de Boisbaudran are some of the names connected with these tables. They serve to show that many minds are attacking the problem and give much hope for the future. If the clear, pellucid truth can be filtered away from the wild and fanciful and false the progress will be more rapid.

Our little systems have their day,
They have their day, and cease to be.

So far, no really good method of graphically illustrating the Periodic Law has been suggested. The spiral

used by de Chancourtois in his really remarkable work has been the favorite method of illustrating it. It has been followed by Lothar Meyer, Mendeléeff, Gibbes, Baumhauer, von Huth, Carnelley and others. Probably a better method for class and teaching purposes is the pendulum-like diagram of Spring, used also by Reynolds and Crookes. Mendeléeff's objection to the curves of Lothar Meyer seems to me valid though many prefer to use these or similarly constructed curves. They are, at any rate, scarcely suited to the needs of the student who is indifferently equipped with mathematical ideas. Two objections can be raised to any and all of these diagrammatic illustrations. In the first place they fail to bring out some of the important conceptions of the system, even obscuring some of the points; and in the second place, they generally include fancies and speculations not essential to this system and not justified by our present knowledge of it. They go too far and like much teaching of science by analogy, are liable to be presented by those using them without due care and precaution. This is especially the case wherever they are looked upon as illustrating the genesis of the elements, about which we still know nothing and should say nothing.

Hartley puts the matter in this way. "The Periodic Law can then be thus stated: The properties of the atoms are a periodic function of their masses. In any graphic representation of the periodic law the fact that it is upon the mass of the atoms that their properties depend should appear prominently. The diagram of Dr. Johnstone Stoney used to illustrate the "Logarithmic Law of Chemistry" has, on this account, alone a pre-eminent importance." This diagram of Dr. Stoney's could scarcely be used by the average teacher because of its complicated nature and the knowledge of mathematical operations required. Surely the greatest requirement is clearness and simplicity. It should appeal readily to the

eye and carry in itself in great measure its own explanation. It should present the details of the law and not some portion of them merely. It should not lead to confusion of thought, nor to erroneous conclusions, nor to unconfirmed dreams and fancies. It is manifest that in the present imperfect state of the system no such diagram is possible. Of all which have been offered I do not know of a single one which is truly helpful, which has not upon it some serious blemish, and so I would give voice to a warning against their use. Some one of the tabulations must serve our purposes for the present as a means of graphic representation.

While it is true that the Periodic System has not told us how these simple bodies which we call elements were generated nor from what they came, while it leaves for the present the so-called Genesis of the Elements a blank and may never contribute anything to raise the veil, it is still true that the System has done much to strengthen the belief in the Unity of Matter and to prove beyond all doubt that these elements are not independent, disconnected units but strangely related and interwoven parts of one symmetric whole. However powerless we may be to decompose these simple bodies and split them up into components, it is becoming every day clearer that they are not truly simple but compound. Of what composed or how, we know not, but through them all there runs the traces of some community of nature. Chemists, in their conservatism, are slow to acknowledge a change in belief, so radical as this, without strong bases of proof, either directly or indirectly experimental. It smacks strongly of the baseless fancies of the early alchemists and the Science cannot afford any more Will-o-the-Wisp chases. But when such great names as those of Wislicenus, Thomsen and our own Remsen lend their weight and influence to the new movement we can follow, using the same caution as our leaders. To quote Remsen "It has been shown by a Russian chemist, Mendeléeff and at the same time by a

German, Lothar Meyer, that the elements are related in a very remarkable way, so closely that it is possible to arrange them all in one table, in which they form parts of a system general. The law governing the variations in properties of the elements is known as the Periodic Law. The limits of this article will not permit any detailed explanation of this remarkable law. The main point that I wish to emphasize is, that the so-called elements are shown to be related to one another and it seems impossible in the light of these facts, to believe that they are distinct forms of matter. It seems much more probable that they are in turn composed of subtle elements and it has been pointed out that all the substances which we now call elements, of which there are about seventy, can be conceived to be made of two fundamental elements combined in different proportions. There does not, however, appear to be any immediate prospect of discovering these fundamental substances."

The Periodic System is giving us a clearer perception of many things and gives promise of a deeper insight into the nature of matter. Yet there are unsolved mysteries connected with these numbers which the chemical world has been puzzling over for nearly half-a-century. What is the meaning of the group-differences and the strange recurrence of certain difference numbers and factors which were noticed by Dumas and Cooke and have fascinated and bewildered a host of others since? Why should the numbers eight and eighteen be so frequently repeated in these differences? Thus we find sixteen as the interval between the atomic weights in the alkali, alkaline-earth, oxygen and other groups (using the old designations). Why should seven be the number of elements in a period? Is there a great law of octaves running through nature, in music, color, and the elemental simple bodies? There is little of practical value to be gotten from such speculations but judging from the large numbers of numerical regularities reported it has proved a seductive field. Lit-

tle is to be gleaned from such work. Strange and puzzling figures occasionally appear but the fanciful erratic nature of most of it can be seen from the connection reduced by some between these numerical regularities and the planetary distances or other matters, equally as far away. Some have sought out mathematical formulas by which the atomic weights might be calculated but without very gratifying success. One of the most persistent dreams of the century, Prout's Hypothesis, seems to have received its quietus for a time at least. Such error is hydra-headed and one can never be sure that all the heads are off.

A grand service has been done Chemistry by the discovery and announcement of this system. Chemists have the short-comings of their science brought clearly to their notice and research which was before somewhat desultory and aimless, a little picking here and there, is concentrated and direct so that the work may tell. And this is well as we enter upon a new century—one whose close is to see us a good hundred years further on than we are now. The gaps must be filled, error eliminated, knowledge perfected, so that we need grope no longer but may walk in the light of truth. The man who takes some little portion of the field and examines the inconsistent statements, and stumbles over the absolute errors, and loses his way along paths upon which research has shed no light at all, must bow his head in shame at the small result of our toil during all these centuries of groping.

Let us then be up and doing. Strive to make some one thing clearer, to brush away some error, or to place one stepping stone securely for the feet that are to follow.*

*Address before N. C. Section Amer. Chem. Soc., F. P. Venable, Raleigh Feb. 22, 1897.

NOTES ON THE EXACT COMPUTATION OF THE QUEEN POST TRUSS.

The Queen Post Truss is extensively used in the construction of ordinary highway bridges, as on account of its simple details it is easily constructed by the average carpenter. As usually built by him, there are no counter braces in the middle panel, so that for an eccentric load, the stiffness of the chord has to be depended upon to transfer part of the load to either abutment. Plate 1 represents a bridge composed of two Queen Post trusses placed parallel to the line of road and sixteen feet apart in the clear. The ends of these trusses rest upon wooden timbers (wall plates) at either abutment and the long vertical rods hold up the suspended beams which extend under the bridge from truss to truss. The joists which hold up the planking of the roadway are placed parallel to the trusses and rest at their ends upon the suspended beams and the wall plates. Any load which comes upon the planking is transferred by these joists, acting as beams, to the suspended beams and wall plates. The load thus transferred to a suspended beam is carried to its ends and thence by the vertical rods to the upper joints of the truss, whence it travels down the rafters or main braces to the abutments. For a uniform load over the bridge both suspended beams carry the same loading and the computation of the stresses in the truss members is made in the usual manner. If, however, a heavy concentrated load, as that due to a road roller or a crowd of people, is supposed to act on only one suspended beam, the investigation is of a different character. The part of this concentrated load which is held up by the vertical rods, meeting at an upper joint of a single truss, will be

called W . At the upper joint, this vertical load W is decomposed by the parallelogram of forces method into components acting down the main brace and along the upper chord respectively. The resulting push along the upper chord is decomposed at the next joint into components acting along the other main brace and vertical. The triangle of forces at this second joint is necessarily the same as that at the first joint, as the horizontal component is the same and the rafters are equally inclined to the vertical. Therefore the stresses in the vertical and rafter at the second joint are precisely the same in character and amount as at the first joint. Hence there will be a tension W , in the vertical rods at the second joint and this tension, pressing the suspended beam upwards against the lower chord, tends to bend it upward. The lower chord is thus in the condition of a beam of length equal to the span and subjected to a single upward force W , acting at one third of its length from one end for equal panel lengths. The force W , causes the lower chord to press upwards against the feet of the rafters, with a force $\frac{2}{3}W$ at the nearest rafter and $\frac{1}{3}W$ at the furthest. As we found the vertical component of the stress in both rafters $= W$, acting downwards, the resultant pressures on the abutments are, $W - \frac{2}{3}W = \frac{1}{3}W$ and $W - \frac{1}{3}W = \frac{2}{3}W$ as should be, by the law of the lever, for the original load W acting at the first joint, the larger reaction occurring at the abutment nearest the load.

The lower chord must be made of sufficient dimensions to act as a beam to safely sustain a vertical force W acting upwards and placed a panel length from one end. The moment is greatest at the force and equals $\frac{2}{3}W$ (its reaction at foot nearest rafter) multiplied by one-third the span or length of lower chord from foot of one rafter to that of the other. In addition, the section of the lower chord must be made large enough to provide for the horizontal component H of the stress in a rafter at its foot. This thrust generally acts at h inches above the center of

the chord, depending on the depth of the notch where the rafter joins the chord, and thus not only causes a uniform stress, in the chord but one due to the moment Hh . The maximum fibre stress in the lower chord at a panel point is that due to the above forces combined with that due to the weight of the chord, for all of these influences cause tension in the top fibre of the chord at a panel point.

With a full live load W at each end of both suspended beams, the stresses in the verticals are W as before. So that the stresses in rods, rafters and upper chord are precisely the same as for the eccentric load first considered. In this case, the stress in the vertical rods $= W$, is exactly balanced by the load W held at foot of rod, so there is force tending to bend the chord. The dead load stresses are of course to be found and added to those caused by the live load,

The above theory is upon the supposition that the "suspended beams" are not fastened to the lower chords. If they are fastened, a load at one suspended beam only, is partly carried by the chord "acting as a beam" and partly by the vertical ties. Reasoning as before, the stresses in the verticals at the other joint are the same as those of the first, giving an upward pull on the chord where the suspension beams meet it. The lower chord in this case, is bent downward at the load and upwards at the other panel points, thus giving a reverse curvature to the chord, so that it can resist bending much more effectively than in the former case, where it was compelled to act as a beam with a span equal to the span of the bridge and was acted on by a full panel load. The exact solution for this case cannot be effected by statics alone. Another principle has to be made use of and I have availed myself of the principle of least work, for which see an article by the writer in the Transactions of the American Society of Civil Engineers for April, 1891.

In this article, the writer deduced the principle of least work, with effect of temperature changes included, by

the method of virtual velocities, to which it readily lends itself. Castiglione in his "Systemes Elastiques," a work that deserves to become classic, had already deduced the principle in an entirely different manner and given numerous applications to structures in metal and stone.

The writer has followed essentially his manner of applying the principle, to the truss next to be examined, though by regarding the chord, when acting as a beam, to be "free" under the action of certain forces, there is a gain in simplicity.

I have computed in full, the truss shown in plate 2, an inverted Queen Truss. As it corresponds exactly in theory to the truss shown in figure 1, if we suppose the suspended beams there to rest on or be fastened to, the lower chord, the solution of the one truss will indicate that of the other.

Reference will be made to the following principles in the theory of elastic work:

In a straight bar of length a and cross section w , subjected to a gradually applied stress which reaches its maximum s , the elastic work of deformation, e being the coefficient of elasticity of the bar is,

$$\frac{1}{2} \frac{a}{ew} s^2 \dots \dots \dots (1)$$

In a beam subjected to vertical external forces, if we call the length of a segment of the beam l and the moments of the external forces, at the right end of the segment M_0 , at the middle M_1 and at the left end M_2 , the elastic work of deformation, of the segment considered is

$$\frac{1}{2EI} \frac{l}{3} (M_0^2 \times 4M_1^2 + M_2^2) \dots \dots \dots (2).$$

E being the modulus of elasticity of the beam.

The principle of least work requires that the sum of the work due to all members of the structure shall be a minimum, when one unknown stress is required.

In the elevation of one truss of the structures shown by fig. 2, the centre line of chord is 45 ft. long and is divided into three equal panels. From centre line of chord to bottom of posts is 4 feet, thus giving the length of inclined rods AC (from washer to foot of post) 15.52 feet and the length of horizontal rods CC 15 feet.

We shall suppose that the two suspended beams on either side of the left post, transfer to the chord through the hangers, a load of 14 thousand pounds and the suspended beams at the right post similarly transfer a load of 4.5 thousand pounds. [All loads, reactions and stresses will be expressed in thousand pounds.]

Call p the part of the load 14 that is supported by the chord acting as a beam and therefore $14-p$ will be the part held up by the left post. The downward thrust of the post on the ties gives a stress in the left inclined tie $= 15.52(14-p) \div 4$ and in the horizontal tie, $15(14-p) \div 4$. This last tension, when resolved at foot of right post into components, gives a tension in inclined tie there and compression in post, the same as found at the left apex C, the triangles of forces being equal at the two apices as the stress in the horizontal tie is the same in both.

The right post thus pushes upwards with a force $14-p$, which is assumed, as we shall find it to be, greater than the load 4.5 applied to chord at right post. The difference $(14-p)-4.5 = 9.5-p$ represents then, the upward thrust against the chord there which must be sustained by the chord acting as a beam.

The chord acting as a beam, therefore sustains a downward force over left post of p and an upward force at right post of $(9.5-p)$. By the law of the lever, these forces cause a downward pressure at the left abutment of $(p-3.166)$ and an upward effort at right abutment equal to $(6.333-p)$.

As the vertical components in both inclined rods are each $(14-p)$ we have, as the total pressure of truss on left abutment, $(p-3.166) + (14-p) = 10.833$ and at right

abutment $(14-p)-(6.333-p)=7.666$, just as we should find for the two original loads by the law of the lever.

These results are true for any value of $p(<14)$ that may be assumed. They do not determine p . We shall soon see how to determine it after expressing the work of deformation of the entire truss in terms of p .

As the elastic work in the vertical posts is very small it will be neglected. The work in the ties is given by formula (1).

For the two inclined ties, the stress, $s=15.5 \times (14-p) \div 4$, $a=15.5$ and $w=.04$ square foot nearly. Substituting these values in (1) and multiplying by 2 we get the elastic work by inclined ties at either end.

Similarly the stress in the horizontal tie CC, $s=15(14-p) \div 4$, also $a=15$ and $w=.04$. These values substituted in (1) gives the work of horizontal rod CC.

As the modulus e is for iron and E for wood, take $e=16E$, then the work of the iron ties in one truss will add up to,

$$\frac{1}{2E}(1075p^2-29600p) \dots \dots \dots (1).$$

on neglecting terms that do contain p , as will be done in what follows, as such constant terms disappear when differentiated as to p .

To ascertain the work on the chord acting as a beam, we use formula (2). We have the downward force p acting at left post, the upward force $(9.5-p)$ at right post, the upward *reaction* at left abutment $(p-3.166)$ and the downward *reaction* at right abutment $(6.333-p)$. The beam can thus be considered as free and subjected to these forces only,

Let us apply formula (2) first to right segment of chord from E to B, 15 feet in length,

$$\begin{aligned} \therefore 2l &= 15, \\ M_0 &= 0, \\ M_1 &= (6.333-p)7.5, \end{aligned}$$

$$M_2 = (6,333 - p)15;$$

giving the work of deformation for this section,

$$\frac{1}{2EI} (1125p^2 - 14250p) \dots \dots \dots (4).$$

neglecting the constant term as before. For the middle segment, $2l=15$,

$$M_0 = (6.3333 - p)15$$

$$M_1 = (p - 3.166)225 - 7.5p$$

$$M_2 = (p - 3.166)15$$

The work by (2) for this segment is therefore,

$$\frac{1}{2EI} (3375p^2 - 32062p) \dots \dots \dots (5).$$

Lastly for the left segment A B, $2l=15$,

$$M_0 = (p - 3.166)15$$

$$M_1 = (p - 3.166)7.5$$

$$M_2 = 0$$

\therefore by (2) work equals

$$\frac{1}{2EI} (1125p^2 - 7125p) \dots \dots \dots (6)$$

Adding together (4), (5) and (6) and for a beam 6×16 inches, putting,

$$I = \frac{1}{12} \cdot \frac{1}{12} \left(\frac{4}{3}\right)^3 = \frac{8}{18},$$

We get as the total work of the chord acting as a beam,

$$\frac{1}{2E} \left\{ 56953p^2 - 541050p \right\} \dots \dots \dots (7).$$

The uniform compression in the chord, $s = 15 (14 - p) \div 4$, causes elastic work given by (1), on substituting, $a=45$ and $w=\frac{2}{3}$ square foot; the amount being,

$$\frac{1}{2E} \left\{ [950p^2 - 26600p] \right\} \dots \dots \dots (8).$$

On adding the expressions (3), (7) and (8), we find for the total elastic work of one truss, neglecting constants,

$$\frac{1}{2E} \left\{ [58960p^2 - 597250p] \right\} \dots\dots\dots(9).$$

By the principle of least work, the derivative of this with respect to p must be placed equal to zero in order to find p .

$$\therefore 117920p - 597250 = 0$$

$$\therefore p = 5.07.$$

So that the chord, acting as a beam, sustains a downward force at the left post of about 5 thousand pounds and an upward force at the right post of 9.5 p or about 4.5 thousand pounds, causing the chord to bend downward at the left post and upward at the right post. This reversed curve assumed by the chord causes it to be more efficient as a beam than in the preceding bridge examined.

The value of the reactions of the chord, acting as a beam, at the ends, we have seen to be,

$$p - 3.17 = 1.90 \text{ and}$$

$$6.33 - p = 1.26;$$

thus giving the greatest moment at the left post equal to $1900 \times 15 = 28500$ foot lbs.

If we allow, by the usual formula, 1200 pounds per square inch fibre stress the chord, for a depth of 16 inches, should be 6.6 inches wide in place of the 6 inches assumed. Certain changes of temperature will increase this width still further as we shall see.

INFLUENCE OF CHANGE OF TEMPERATURE.

The linear expansion of iron, per unit of length, for each degree centigrade (1°C), is $1 \div 82500$.

Suppose the bridge put together at 10°C 50°F and that

the temperature afterwards rises $t=25^{\circ}\text{C}$ (45°F). If the expanded horizontal bar CC is supposed in position, the end bars AC and EC will each be too long by

$$\frac{1}{2} \frac{15t}{82500} \cos i + \frac{15.52t}{82500} = .000276t$$

where i = angle that end bar makes with chord.

The tension in end rod or tie is

$$15.5 (14 - p) \div 4$$

Twice the product of these two expressions, or,

$$(constant - .00214t)$$

gives the work due to heat in the truss, neglecting any expansion of the wood.

By the article of the writer referred to above (Section 6), we must add this term to the elastic work (9) of the entire truss and put the derivative with respect to p equal to zero. Doing this we obtain,

$$58960p - 298625 - .00214tE = 0.$$

If we assume E for yellow pine, 1,600,000 pounds per sq. inch, or, as we must substitute it here, where all dimensions are in feet and loads in thousand pounds,

$$E = 230400 \text{ thousand pounds per sq. foot,}$$

we derive,

$$58960p - 298625 - 493t = 0 \dots \dots (10),$$

$$\text{whence for } t = +25(\text{C}), p = 5.27$$

$$\text{and for } t = -25(\text{C}), p = 4.85.$$

The rise of temperature of 25°C (45°F) above the supposed normal of 10°C (50°F) gives the greatest reaction, 2103 pounds, at left abutment, and hence the greatest moment = 2103×15 foot pounds at left post. This moment calls for a beam 7.4 inches wide by 16 deep. It was made 8 inches wide to allow somewhat for the uniform compression, which, however, is less than 300 pounds per square inch on account of the large section of the chord. At the left post, the weight of the chord

tends to cause tension in the upper fibre. Its influence being beneficial, was not further regarded.

The method has now been given in full for ascertaining the stresses in the various members for a non-uniform loading.

□ In this particular case, the dead load per panel per truss, was assumed at 4500 lbs., which is found to be nearly exact on making out weights, etc.

The live load was assumed to be that due to a crowd of people weighing nearly 80 lbs. per sq. foot, for a clear width between trusses of 16 feet; the portion held at one apex of one truss being 9500 pounds. As such a partial load can only be obtained by supposing the live load to extend from an abutment two panels and then neglecting the part held up at the farthest apex, it is in excess of any eccentric load that can be placed only at one apex and thus is on the side of safety.

The influence of temperature changes is seen to be very marked for this combination bridge and would be still more pronounced for more northern latitudes, where greater ranges of temperature are experienced than in the Southern states. By giving any desired value to t in equation (10) above, the resulting value of p is readily found and the chord examined as before for proper width.

It would materially tend to obviate the bad effects of temperature if the truss was assembled in the heat of summer without any camber in the chord. As it became colder, the chord would receive a slight camber upwards, which would increase with the fall of temperature, and thus tend to diminish the large bending stress in the chord at the most heavily loaded apex. For this case, we should put, say, $t = -50$ in eq. (10) and thus find $p = 4.65$ and finally the resulting maximum moment in the chord acting as a beam which turns out to be at the right post where no live load is supposed to rest. It is 1683×15 ft. lbs., and thus less than for the temperature at which the

bridge is assembled; so that no increase of stress is experienced, but the reverse and the width of chord can be safely taken at 6.6 inches, or say 7 inches, for a depth of 16 inches, as first found.

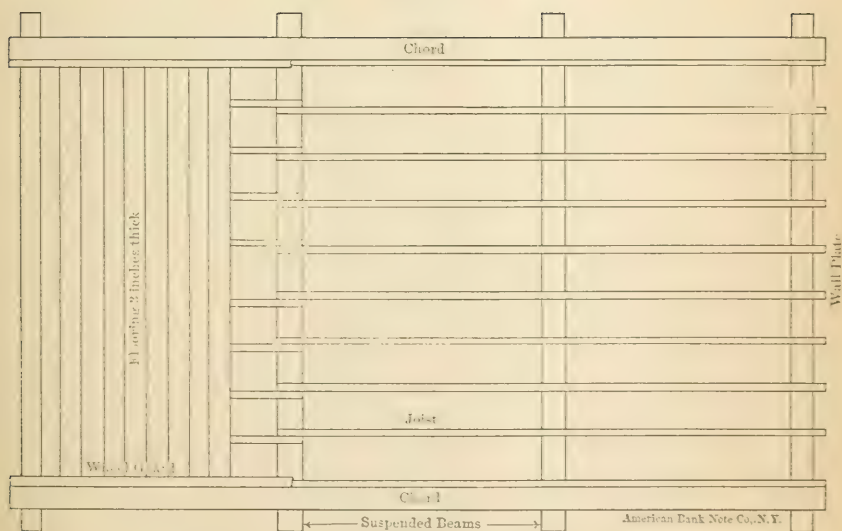
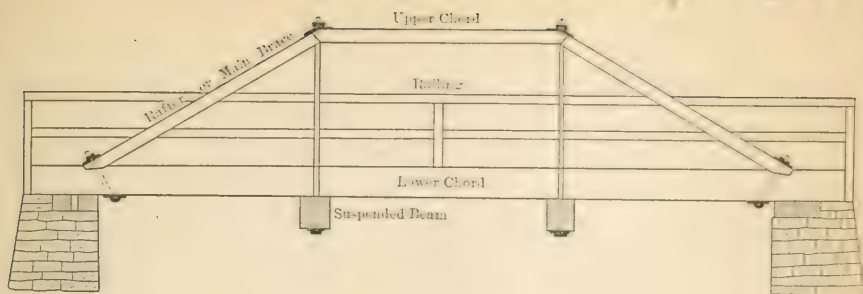
The maximum stresses in the ties and posts are of course under a full loading of 14,000 pounds at each post. The chord now bends downwards throughout so that it cannot sustain near as much of the load (acting as a beam) as before. The strict investigation can be made as above; but it may prove near enough in determining the section of the ties (the posts evidently having an excess of strength) to suppose each post to carry the full panel load in place of the strict value ($14-p$), to the ties and proportion them for the corresponding stress in an end tie, as their section is uniform throughout. The section given was determined in this way for an assumed unit stress of 10,000 pounds per square inch.

SOME LATE VIEWS OF THE SO-CALLED TACONIC AND HURONIAN ROCKS IN CENTRAL NORTH CAROLINA.¹

BY H. B. C. NITZE.

The region under discussion embraces a belt, from 8 to 40 miles in width, of metamorphic slates and schists, extending from Virginia in a general southwesterly direction across the central part of North Carolina into South Carolina. This area forms the principal gold ore belt

¹For further discussion of this subject and for map showing the distribution of the rocks here described, see Bulletin 3 N. C. Geological Survey, 1896.



QUEEN POST TRUSS
Floor Plan

Plates kindly loaned by Prof. J. A. Holmes, State Geologist.

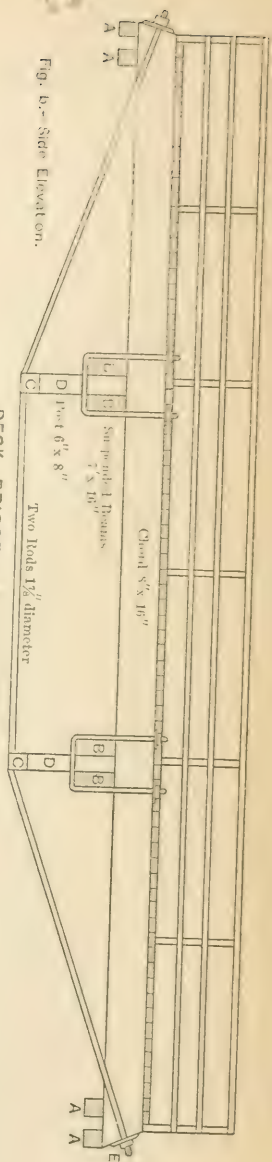


Fig. c.
Detail of Iron Washer



Fig. d.
Detail of Iron Shoe

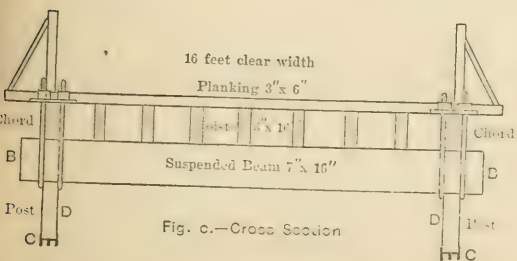
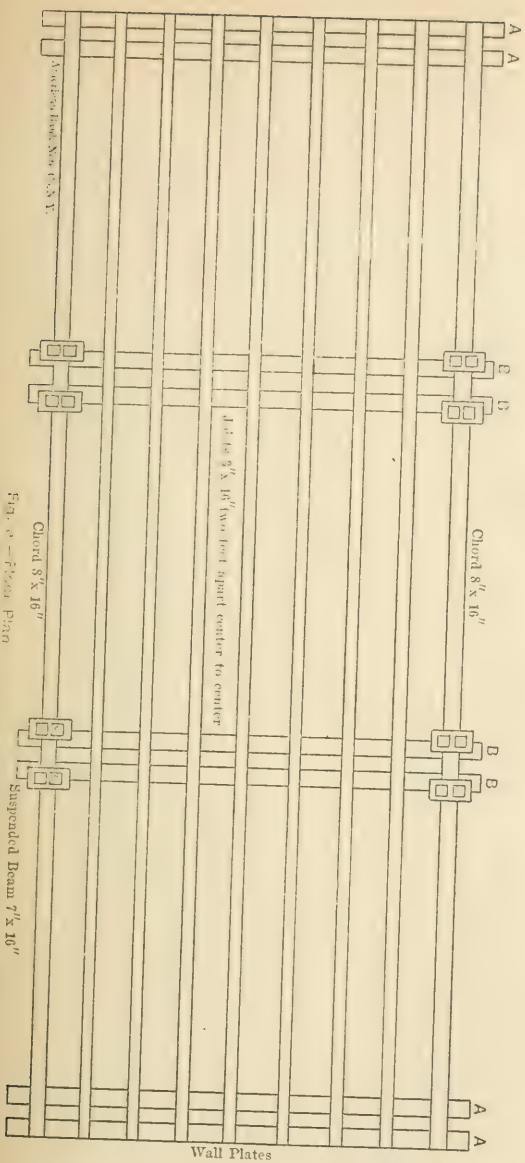


Fig. c.-Cross Section

Fig. a.-Plan View
Plates kindly loaned by Prof. J. A. Holmes, State Geologist.

ERRATA.

In eq. (1), p. 48, for 1075 read 1057.

On p. 49, line 7, for 225 read 22.5.

“ “ “ 19, for $\frac{1}{12} \frac{1}{12} (\frac{4}{3})^3 = \frac{8}{18}$, read $\frac{1}{12} \frac{1}{2} (\frac{4}{3})^3 = \frac{8}{81}$.



of North Carolina, in which connection it is known as the Carolina Slate Belt. It includes, in North Carolina, portions of the counties of Granville, Person, Durham, Orange, Alamance, Chatham, Randolph, Davidson, Rowan, Moore, Montgomery, Stanly, Cabarrus, Anson, and Union. On the west it is bounded by an area of igneous crystalline rocks, and on the east, for the greater part, by the Jura-Trias sandstones, conglomerates and shales.

The general term *slates and schists*, used above, covers a broad designation. The country rocks of the region are:—1) Argillaceous, sericitic (hydro-micaceous), and chloritic slates and schists, all of them more or less metamorphosed. 2) Sedimentary pre-Jura-Trias slates. 3) Ancient volcanic rhyolites, quartz-porphyrries, etc., and pyroclastic breccias, often sheared into a schistose structure. The general strike of the schistosity is N. 20° to 50° E., and the dip is steeply to the northwest.

In 1856, Prof. Ebenezer Emmons, in his *Geological Report of the Midland Counties of North Carolina* (pp. 38–73) described this region and referred the rocks to the Taconic system; and in 1875, Prof. W. C. Kerr, in his *Report of the Geological Survey of North Carolina* (vol. 1; pp. 131–139) included the same rocks in the Huronian.

In order to gain a more comprehensive oversight of this important geological area, it will be well to first state briefly both Emmons' and Kerr's conceptions of their Taconic and Huronian in this part of North Carolina; and then to discuss the same in the light of more recent investigations, carried on by the writer during the latter part of 1894, for the North Carolina Geological Survey. These investigations were unfortunately of a cursory and incomplete nature, and can but form the beginning of a more thorough study of the region later on. However, they will well serve the present purpose of showing the errors into which Emmons and Kerr had fallen, and the miscon-

ceptions they entertained regarding the nature of these rocks, due perhaps chiefly to the lack of petrographic evidences, the science of microscopic petrography being totally unknown in Emmons' days, and certainly in its infancy at the time of Kerr.

EMMONS' TACONIC SYSTEM IN NORTH CAROLINA.

Emmons placed these rocks among the oldest sedimentaries, i. e. at the base of the Paleozoic. In his words:¹ "The formation of the midland counties, which occupy the largest extent of surface, are slates and siliceous rocks, which have been called quartzites." * * * * "The slates are variable in color and composition. They are mineralogically clay, chloritic, and talcose slates, taking silica into their composition at times, and even passing into fine grits and hornstones, but still variable in coarseness. In the order in which they lie the talcose slates and quartzites are the inferior rocks, though quartzites occur also in the condition of chert, flint or hornstone in all the series."

He established their sedimentary origin from the occurrence of numerous beds containing, in his belief, rounded pebbles. Further, "I found, however, many beds among them which looked like sediments, were porphyryized and somewhat changed, though not strictly porphyries. I found after much search too, beds which were unequivocally pebbly; and finally, to remove all doubt, I was fortunate in discovering that the porphyryized beds also frequently contained pebbles; proving most conclusively that they are sediments which were partially altered."²

One of the arguments that Emmons used to prove the sedimentary nature of the Taconic, and its derivation from the basal complex, is the presence of gold in the

¹ Geol. Report of Midland Counties of N. C.

² Ibid, p. 47.

slates and schists, "which of course must have been commingled with the sediments at the time these rocks were deposited." * * * * "The gold exists mostly in the western belt of granite in the veins belonging to the hornblende and gneiss of the Blue Ridge."¹

Furthermore he claimed to have discovered in his Lower Taconic sandstones and cherty beds at Troy and Zion (12 miles southwest of Troy) in Montgomery county, several species of fossils.² He described these as siliceous corals of a lenticular form, from the size of a pea to two inches in diameter. Two varieties are distinguished and named by him: *Paleotrochis* (old messenger) major and, *Paleotrochis* minor. The following descriptive section, in the ascending order of the rocks and beds, in which these supposed fossils were found, is given:

"(1) Talcose slates, passing into siliceous slates, and which are often obscurely brecciated. Thickness undetermined.

"(2) Brecciated conglomerates, sometimes porphyrized.

"(3) Slaty breccia, associated with hornstone.

(4) Granular quartz, sometimes vitreous and filled with fossils and siliceous concretions of the size of almonds; two to three hundred feet thick.

"(5) Slaty quartzite with very few fossils; about fifty feet thick.

"(6) Slate without fossils; forty feet thick.

"(7) White quartz, more or less vitrified, filled with fossils and concretions; seven to eight hundred feet thick.

"(8) Jointed granular quartz, with only a few fossils.

"(9) Vitrified quartz without fossils, and thickness very great, but not determined,

"The fossils also occur in the variety of quartz or quartzite known as burrstone, and which is often porphyrized."

¹ Ibid, p. 57.

² Ibid pp. 48, 60.

These fossiliferous beds are stated to be sometimes auriferous.

He is therefore disposed from the above facts, to place all of the rocks not decidedly igneous, that is, those which he regarded as stratified (though in reality the apparent stratification is but schistose lamination), with the sediments. He then correlates these rocks with the taconic, the infra-silurian sediments of Massachusetts, based mainly on "their lithological characters, and the relations in which they are placed to the older rocks, and those which they sustain to each other." In North Carolina, he says, these rocks have been derived from syenitic granites, which he believes to belong to the primary or basal complex. He makes two divisions, the Lower Taconic and the Upper Taconic, noting that the distinction between them, however, is less obvious in North Carolina than in the northern equivalents.

The Lower Taconic, "The Lower series will contain the talcose slates, white and brown sandstone, or quartz, which is frequently vitrified or cherty, and the granular limestone and associated slates."¹

The talcose slates are stated to be made up of talc and fine grains of quartz, becoming a friable sandstone when quartz predominates. Color and lustre silvery when chlorite is absent, and greenish when chlorite is present. The following varieties of these quartz rocks are given:²

"(1) A fine grained coherent quartz.

"(2) A fine grained friable quartz.

"(3) A fine grained micaceous and talcose quartz.

"(4) Vitrified quartz or chert. (a) green, blue, (b) agatized.

"(5) A cherty or apparently porphyrized quartz, which contains feldspar, which decomposes and leaves a rough porous mass similar to burrstone.

¹ Ibid, p. 49; Ibid, p. 51

² Ibid, p. 55.

"(6)Pebbly and semi-brecciated quartz.

"(7) Common brown quartz.

This rock * * * * is associated with * * * talcose slates. It is repeated two or three times. * * * It frequently contains beds of pebbles. But its most interesting feature appears in its passage into hornstone, chert or flint."

The apparent vitrification he considers due to a chemical combination of the particles, that is, to a cause independent and distinct from heat.

"Agalmatolite" (pyrophyllite) is mentioned as occurring in beds in this Lower Taconic series. And limestone, containing talc and tremolite, is said to be associated with slate and quartz,

Emmons' rocks of the Lower Taconic, then are:¹

(1) "Beds of talcose slates. (2) Quartz rocks with their alternating series of talcose slates. (3) Beds of agalmatolite. (4) Limestone with its interlaminated slates.

The Upper Taconic. "This division of the system is not very clearly marked. * * * In North Carolina the line of demarcation is sometimes difficult to define. But the rocks which I regard at the present time are (in ascending order)²:

(1) "Argillaceous, or clay slates, with many subordinate beds, roofing slates, mountain slate.

(2) "Chloritic and argillaceous sandstones, flagging stones, etc.

(3) "Brecciated conglomerates.

The ordinary soft, greenish slates may be regarded as the prevailing mass of the first division. The predominant color is greenish gray. A red decomposed variety is mentioned as being common near Pittsboro, Chatham county. "The subordinate beds are fine siliceous ones passing into chert or hornstone. * * * The colors are blue, purple and green."

¹ Ibid, p. 55.

² Ibid p. 65.

"The slate in the ascending order is more and more interlaminated with thick beds, which have an intermediate composition between a sandstone and slate, the second division. * * * Among them are beds of conglomerate. These beds may be mistaken for trap, being greenish and tough, and besides like trap the broken strata become concretionary and exfoliate in concentric layers."

"The brecciated conglomerate has an argillaceous or chloritic base. The mass is composed in the main of fragments of other rocks mostly retaining an angular form. The fragments are sometimes eighteen inches, and even two feet long."

"The clay slates and breccia, with their intermediate beds are traversed by veins of milky quartz. They are sometimes auriferous."

The so-called quartzite of both the Upper and Lower Taconic is considered of such peculiarity that a separate chapter is devoted to its description. It is described as an uncrystallized quartz, resembling gun-flint, and is also called flint, chert and hornstone. Color bluish-black, passing to purple, grayish, white and green; sometimes banded; texture fine when compared with the finest sandstone; translucent on edges; fracture flat conchoidal; often porphyritic, porphyryzed; and it is stated that frequently the fresh fracture is dotted with small limpid crystals of quartz.

"The varieties of quartzite are numerous if color and texture are made grounds of distinction:¹

- (1) "Light gray and compact, or very finely granular.
- (2) "Smoke gray, with grains of hyaline quartz disseminated in the mass.
- (3) "Texture fine granular, with drab color.
- (4) "Porphyryzed quartzite.
- (5) "Light green quartzite.

¹ Ibid, p. 71.

(6) "Greenish, and full of cavities, and frequently epidotic.

(7) "Banded quartzite, or coarsely agatized.

"These forms of quartzite are not confined to rocks of a particular age, or to a given series. They seem to be distributed through formations of all ages and epochs. They are common to both divisions of the Taconic."

Emmons explains their origin from an aqueous chemical standpoint.¹

KERR'S HURONIAN SYSTEM IN CENTRAL NORTH CAROLINA.

Kerr recognized five principal outcrops of the Huronian rocks. The one that corresponds to the Central Slate belt, and hence of interest here, is stated to lie on the west side of the Raleigh granite.² "The bottom beds are argillaceous and talcoid.* * * Three or four miles from Raleigh these slates become highly plumbaginous,* * * and a heavy body of micaceous, white, slaty quartzites follows closely along the west side of the graphite.

Alternations of argillaceous, talcoid and quartzitic beds continue for five or six miles, when they disappear beneath a narrow trough of Triassic sandstones, beyond which they emerge along an irregular, but approximately northeast and southwest, line in the central mineral bearing slate belt. * * * This tract extends quite across the State in a breadth of 20 to 40 miles, and is composed of siliceous slates and clay slates chiefly; the former being often brecciated and conglomerate, the pebbles sometimes a foot and upwards in diameter, frequently chloritic, and often passing into hornstone and chert, and occasionally into quartzite. The clay slates are generally thin-bedded, often shaly, gray, drab, banded, blue and frequently greenish from an admixture of chlorite; sometimes tal-

¹Ibid. pp. 51 and 72.

²Report of the Geol. Sur. of N. C., 1875, Vol. 1, pp. 181-9,

coid or hydro-micaceous; and very often they may be better described as conglomerate slates, being composed of flattened and differently colored soft, slaty fragments of all sizes, from minute particles to an inch and more in diameter. * * * * * In Montgomery county, in a very heavy ledge of siliceous slates, occurs a siliceous conglomerate, which is filled for hundreds of feet with very singular siliceous concretions, some of which Dr. Emmons has described under the name of *Paleotrochis*; but the rock for several miles, as well as at this particular locality, contains a multitude of rounded and ovoid masses from the smallest sizes to that of a hen's egg; showing the wide prevalence of conditions favorable to the operation of concretionary forces. * * * The talcose, siliceous, chloritic slates are more abundant towards the base of the series, the east side, and the clay slates predominate on the west."

He also mentions the occurrence of beds of pyrophyllite, and the abundance of quartz veins. The strike is given as northeast, and the dip prevalently west at steep angles.

"The belt is bounded on both sides by the Laurentian, on which it lies unconformably, and from which its materials were derived. The stratigraphy therefore indicates the horizon of these rocks to be the Huronian, and lithology agrees with that determination."¹

RESULTS OF MORE RECENT PETROGRAPHIC STUDIES.

The Slates and Schists. One of the results of the late geological work in this belt has been to identify at least the argillaceous, sericitic, and chloric schists and slates with those of Emmons' Taconic and Kerr's Huronian. These rocks are termed schists, and again they are termed slates. Certainly a great number of them have a true slaty cleavage, while others are more truly schistose, i. e. the laminae are not essentially parallel. These different

¹ *Ibid*, p. 133.

structural effects are due to dynamo-metamorphic action on materials of different composition. The argillaceous types might more properly be called the slates (clay-slate, thon-schiefer, argyllite, phyllite) as they contain more uncrystalline matter, and possess a more definitely slaty structure. So also bedding planes are more easily distinguishable in these, if at all; and altogether their sedimentary or clastic origin is more evident. At the same time they are metamorphosed in varying degrees, and possess many secondary cleavage structures. These slates often have a calcareous tendency in their composition, as is exemplified by the numerous small calcite seams that intersect them, and the coatings of calcite on their cleavage planes.

The term *talc* (*talcose*, *talcoid*) slate or schist, used by Emmons and Kerr, and generally by many others, is a mistaken one. It is true that it is perhaps an excusable error, for these slates and schists are often so soft and greasy that the resemblance to talc is very great. However, chemical analysis and other characteristics would place the mineral in the class of hydro-muscovite or sericite, the percentage of magnesia being far too small for talc. Several analyses of type specimens of this rock from the Haile gold mine in Lancaster county, S. C., by Dr. Chas. Baskerville, of the University of North Carolina, show:

| | | |
|--------------------------------|--------------|-------------|
| SiO ₂ | 44.61 | 61.02 |
| Al ₂ O ₃ | 31.57 | 25.54 |
| FeO | 3.55 | 4.46 |
| CaO | 0.20 | 0.60 |
| MgO | 0.22 | 0.14 |
| MnO | 0.16 | ..... |
| Na ₂ O | 6.96 | 2.19 |
| K ₂ O | 6.97 | 1.81 |
| H ₂ O | 5.80 | 4.20 |
| | <hr/> 100.04 | <hr/> 99.96 |

The term that I shall therefore use as more appropri-

ate is sericite schist. The true talc schists are very rare.

The chloritic schists are probably more truly crystalline schists, and are richer in accessory metamorphic minerals, such as garnet and epidote.

The argillaceous slates and sericite schists are frequently silicified; the chlorite schists are not as a rule. This silicification exists in varying degrees up to a completeness which renders the rock so hard that it resists scratching with a knife.

The strike of the formation as a whole is generally northeast, and the dip steeply to the northwest. These strikes and dips refer to the schistosity of the rocks, and not to the bedding planes.

In general the force producing schistosity and slaty cleavage appears to have acted downward from the northwest, producing normal faulting with but little deformation. No instance of reverse faulting was recorded.

Now, as to the origin of these schistose and slaty rocks; in part it seems that they must be sedimentaries altered by dynamo- and hydro-metamorphism. The evidence of this is offered by several observations of bedding and banding extending across the schistosity, generally at low angles, although in most instances this original structure has been obliterated. Emmons' supposition that the gold in the slates and schists is of sedimentary origin (page 55) is altogether untenable.

The lamination or schistosity, however, is wholly the effect of shearing, produced by dynamo-metamorphism. It has no connection with bedding planes of stratigraphic structure, as both Emmons and Kerr supposed. The original bedding planes may correspond to certain of the present cleavage planes, i. e. lie parallel to them, but in that case the bedding structure has been obliterated. Schistosity must not be confounded with bedding.

It does not seem probable, at the present stage of investigation, that these slates have been derived from the granitic and other more basic igneous masses lying on

the west; for these are supposed to be later intrusive bosses.

That others of these schists, particularly the chloritic varieties, are metamorphosed, sheared eruptives seems most probable. They are even porphyritic and brecciated in places. In fact Emmons hints at such rocks in his description of his Upper Taconic chloritic member, when he says: "These beds may be mistaken for trap, being greenish and tough, and besides like trap, the broken strata become concretionary and exfoliate in concentric layers." (Page 59.) This subject will be recurred to later on.

The Monroe Slates. At Monroe, in Union county, a considerable area of truly bedded and but little indurated or metamorphosed slates was discovered. Similar slates were also found at the Parker gold mine near New London, Stanly county, at the town of Albemarle in Stanly county, and at the Sam Christian gold mine in Montgomery county. Thus they presumably cover a large area in the southeastern portion of the Carolina Slate Belt. In the fresh condition this slate is black, weathering to dark and light drab, greenish and even reddish colors. At the railroad station (Monroe) it lies in a low, gently undulating anticlinorium. Several hundred yards south of the depot the strike is N.85°E., and the dip is 30°S.E. At a point $\frac{1}{2}$ mile north of the depot it is finely banded and lies nearly horizontal. It has been quarried here for use as paving blocks in Monroe.

That these slates are of sedimentary origin and of later age than the slates and schists to the west and north can scarcely admit of doubt. They are reported to dip under the Jura-Trias conglomerate at Polkton, about 20 miles east of Monroe, and might be looked upon as Lower Paleozoic; but the absence of fossils (at least so far none have been found, though a careful search is certainly warranted) must, for the time being, place them provis-

ionally in the Algonkian. They might appropriately be named the *Monroe* slates.

The Volcanic Series. The middle member of Emmons' Lower Taconic is the quartz rock (white and brown sandstone), which is stated by him to exist in many varieties; (p. 57). I did not observe any true granular quartzites, such as characterize the Cambrian for instance (even in a metamorphosed state); and in fact, from Emmons' and Kerr's descriptions, their rocks of this class are rather fine-grained, thin bedded, quartzose schists, and devitrified quartz or chert, often porphyrized and brecciated. It is probable that Emmons' fine grained talcose quartz (p. 58) corresponds to the silicified schists, (p. 63) whose quartzitic nature is due to a later hydro-silicification.

The crypto-crystalline varieties of quartz (flint, chert, hornstone) are of especial interest, and warrant a careful consideration. It is at present the opinion that these rocks belong to the class of ancient (pre-Cambrian) acid volcanics, in many respects analogous to, and probably contemporaneous with, similar rocks of the South Mountain in Maryland and Pennsylvania, whose discovery was first announced by the late Dr. George H. Williams.¹ Miss Florence Bascom has described the origin, devitrification and structure of the acid types of these rocks.² And Dr. Williams has outlined the general distribution of the ancient volcanic rocks along the eastern border of North America.³ These rocks are analogous also to the halleflintas and eurites of Southern Sweden, described as volcanic rocks by Nordenskjöld. They would also correspond to Hunt's pre-Cambrian petro-silex rocks, called by him the Arvonian, being below his Huronian.

The hornstones have every appearance of being acid feldspar quartz rocks, and will probably be found, on

¹ The Volcanic Rocks of the South Mountain in Pa. and Md. Am. Jour. Sci. xliv., Dec. 1892. pp. 482—496.

² Jour. Geology, Vol. 1. 1893. pp. 813—832.

³ Jour. Geology, Vol. 2. 1894. pp. 1—31.

further study, to belong to the class of apo-rhyolites, a term introduced by Miss Bascom to denote a devitrified rhyolite. Emmons describes the type very well under the head of quartzite (p. 59). They resemble perfectly crypto-crystalline quartz, and on weathering present an earthy, yellowish surface. The color of the fresh rock is drab, bluish to almost black; translucent on edges; fracture flat conchoidal; sometimes banded, showing flow structure, as at the Silver Valley mine in Davidson county, where the rock is locally called "gun-flint." It often contains small crystals of metallic sulphurets, chiefly pyrite with some galena, chalcopyrite and blende.

At the Moratock gold mine in Montgomery county, a siliceous rock occurs in large masses, which at first sight resembles a compact, homogeneous hornstone, but which on close investigation is found to be dotted with small, dark-colored, glassy specks. These are minute quartz crystals, and the microscopic examination of thin sections shows the rock to be an undoubted quartz-porphry. Its true porphyritic character is best illustrated in the weathered specimens, the feldspathic groundmass being decomposed and altered, leaving the quartz phenocrysts clearly outlined. The flow structure is also beautifully brought out in the weathered groundmass.

Emmons, in his description of his quartzite, states that it is often porphyritic and porphyrized, and that frequently the fresh fracture is dotted with small limpid crystals of quartz (p. 59).

In the enumeration of the varieties of Lower Taconic quartz rocks (p. 57) he mentions a cherty or apparently porphyrized quartz, which contains feldspar, which decomposes and leaves a rough porous mass similar to burrstone." Kerr says: "In Montgomery county, in a very heavy ledge of siliceous slate, occurs a siliceous conglomerate which is filled for hundreds of feet with very singular, siliceous concretions, some of which Dr. Emmons has described under the name of Paleotrochis;

but the rock for several miles, as well as at this particular locality, contains a multitude of rounded and ovoid masses, from the smallest sizes to that of a hen's egg, showing the wide prevalence of conditions favorable to the operation of concretionary forces" (p. 61). These gentlemen have without much doubt described the quartz porphyry of the Moratock mine, or one similar thereto.

It appears highly probable that at least some of these siliceous, so-called pebbly concretions are spherulites. Whether they constitute Emmons' pebbly beds, from which he determined the sedimentary origin of his Taconic, is not known. However, it is quite possible that they misled him in that direction. Certain it is that he says: "I found, however, many beds among them (slates and associated rocks) which looked like sediments, were porphyryzed, and somewhat changed, though not strictly porphyries. I found after much search too, beds which were unequivocally pebbly; and finally, to remove all doubt, I was fortunate in discovering that the porphyryzed beds also frequently contained pebbles; proving most conclusively that they are sediments which were partially altered" (p. 55).

Thus he evidently mistook either the concretionary form of the weathered porphyry and felsite, or else the partially rounded felsite fragments in the accompanying pyroclastic breccias (which will be spoken of later on) for pebbles.

¹Prof. Marsh in 1857 made a short study of Emmons' Paleotrochis, and in his words: "An examination of the interior of several specimens clearly indicated that they were not corals, and as soon as microscopical specimens could be prepared, they were more carefully examined, but no trace of organic structure could be detected, the entire mass being evidently a fine grained quartz. The specimens examined were undoubtedly authentic examples

¹Am. Jour. Sci. (2), Vol. 45, 1868, p. 217.

of Paleotrochis, as some of them presented to the Yale cabinet by Prof. Dana, were sent to him by Prof. Emmons, and the rest were given to the writer by Prof. W. C. Kerr, the present state geologist of North Carolina. * * * * Admitting the inorganic nature of these remarkable forms, their origin becomes an interesting question, and it certainly is not easy to give a satisfactory explanation of it. They appear, however, to have some analogy with "cone in cone," which, as the writer has shown elsewhere,¹ is probably due to the action of pressure on concretionary structure when forming. In some respects the two are quite distinct, but evidence of pressure is clearly to be seen in both."

Kerr evidently agreed with Marsh as to the inorganic nature of the Paleotrochis, and Mr. C. D. Walcott, the director of the U. S. Geological Survey, entertains the same opinion.²

According to both Emmons' and Kerr's descriptions, these peculiar forms appear to occur in what are now known to be the acid effusive rocks. In his descriptive section of the rocks which carry the Paleotrochis, Emmons names the following (p. 56):

"Granular quartz, sometimes vitreous and filled with fossils and siliceous concretions of the size of almonds.

"Slaty quartzite with very few fossils.

"Slate without fossils.

"White quartz more or less vitrified filled with fossils and concretions.

"Jointed granular quartz with only a few fossils."

And he says: "These fossils also occur in the variety of quartz or quartzite, which I have described as burrstone, and which is often porphyryzed." (p. 56.)

An interesting point is suggested in the above succession of rocks, namely, that there was more than one vol-

¹Proc. Amer. Assoc. Adv. Sci., vol. 16, 1867, p. 135.

²Private communication to the writer.

canic outbreak, and during at least one period of inactivity sedimentary slates (the Monroe slates) were deposited.

These acid volcanics are accompanied by pyroclastic breccias and basic eruptives. The basic rocks are of dark green color, and are perhaps pyroxenic in composition. They cover large areas, and are often massive or only partly schistose; again they are largely sheared into schists. It is quite probable that most of the *chloritic* schists in this part of the Carolina Slate Belt are of this nature.

The breccias consist of this basic material in which are imbedded angular fragments of the felsite (apo-rhyolite) or porphyry up to one foot in diameter. They are distinctly pyroclastic breccias and hence the basic rock, or porphyrite as it may be provisionally called, is later than the quartz porphyries and rhyolites. This would agree with the generally accepted law of eruptions, i. e. from the normal to the acid to the basic types.

Emmons, in his description of the Upper Taconic, mentions brecciated conglomerates as the most remarkable mass of this division. As he states, "It has an argillaceous or chloritic base. The mass is composed in the main of fragments of other rocks, mostly retaining an angular form; but frequently rounded and worn rocks are enclosed in the mass. The fragments are sometimes 18 inches and even 2 feet long." (p. 59.)

Kerr mentions brecciated and conglomerated (siliceous slates, the pebbles sometimes a foot and upwards in diameter, frequently chloritic and often passing into hornstone and chert, and occasionally into quartzite" [p. 60]). That these rocks correspond to the above described pyroclastic breccias is at once evident.

These ancient volcanics have also been found covering large areas in Chatham and Orange counties, near the eastern edge of the Carolina Slate Belt, and fully 40 miles east of the region including the above described

localities. During the summer of 1893, Dr. George H. Williams in company with Prof. J. A. Holmes, State Geologist of North Carolina, made a reconnaissance trip through Chatham and Orange counties, the results of which are included in Dr. Williams' paper on the distribution of the ancient volcanic rocks in eastern North America.¹ He says: "In a drive from Sanford to Chapel Hill an abundance of the most typical ancient lavas, mostly of the acid type, was encountered. On the road from Sanford to Pittsboro purple felsites and porphyries showing spherulitic and beautiful flow structures, and accompanied by pyroclastic breccias and tuffs, were met with two miles north of Deep river, and were almost continuously exposed on Rocky river. Here devitrified acid glasses with chains of spherulitic and eutaxitic structure were collected, while beyond, as far as Bynum on Haw river, four miles northeast of Pittsboro, the only rocks seen were of the same general character. On the farm of Spence Taylor, Esq., in Pittsboro, a bright red porphyry with flow lines is exposed in so altered a condition that it can easily be cut into any form with a knife, though it still preserves all the details of its structure. * * *

Three-quarters of a mile beyond Pittsboro, on the Bynum road, there is a considerable exposure of a basic amygdaloid. South of Hackney's Cross Roads there are other excellent exposures of ancient rhyolite with finely developed spherulitic and flow structures. * * * Another locality in the volcanic belt was visited on Morgan's run, about two miles south of Chapel Hill. Here are to be seen admirable exposures of volcanic flow and breccias with finer tuff deposits, which have been extensively sheared into slates by dynamic agency. Towards the east and north these rocks pass under the transgression of Newark sandstone. * * * From still another locality at the Cross Roads near the northern boundary of

¹ Jour. Geol., vol. 2, 1894, pp. 1-32.

Chatham county, fifteen miles southwest of Chapel Hill. Professor Holmes informs me that specimens of undoubted volcanic rocks have recently been secured. He has also sent me, within the past month, a suite of similar specimens from Pace's Bridge, on Haw River, three miles above Bynum."

Since that time the same volcanics have been found at the Narrows of the Yadkin river, along the Deep river at Lockville, and for five or six miles northwest of Lockville. At the last two localities the masses are often brecciated and usually sheared into perfect crystalline chloritic schists.

It is of interest to note, in the above descriptions of Dr. Williams, the occurrence, on the Taylor farm near Pittsboro, of a bright red porphyry with flow lines, in so altered a condition that it can be easily cut into any form with a knife. This is undoubtedly the same rock, and from the same locality, as that described by Emmons as a decomposed red variety of his Upper Taconic argillaceous or clay slate, (p. 58).

Conclusions. In this brief resumé, then, we can recognize Emmons' Taconic and Kerr's Huronian rocks of the central gold-bearing slate belt.

The bitter controversies regarding the Taconic question among geologists are well known, and need not be taken up here. It is sufficient to say that geologists by later and more detailed work and study have seen fit to differentiate various members of the old Taconic system in different parts of the country, and refer them to more definite horizons. Thus the granular quartz of Emmons' typical Taconic section in the Berkshire Hills of Massachusetts, has been found to be characterized by the Olenellus fauna of the Lower Cambrian; and the Berkshire or Stockbridge limestone by the Chazy-Trenton, and perhaps at its base by an Upper Cambrian fauna; and the original Lower Taconic slate of Emmons is correlated, by its stratigraphic position, with the Hudson

shales.¹ In 1888, Walcott, in studying a section of these rocks in Newfoundland, placed, from paleontological evidences, the "Red Sandrock" series, the Georgia shale and slate series, the "Granular Quartz" and "the Upper Taconic" of Emmons beneath the Middle Cambrian or Paradoxides zone of the Atlantic coast.²

And so the rocks of the old Taconic or Huronian belt in central North Carolina must also in time be differentiated and recorrelated when they have been more carefully studied.

Emmons was in a measure quite correct in calling his Taconic rocks of central North Carolina the bottom sediments, and placing them below the Silurian. The absence of fossils in the slates, however, necessitates our going back still another step, and placing them below the Cambrian sediments, in the Algonkian, which Van Hise has defined as including all recognizable pre-Cambrian clastics and their equivalent crystallines, the base of the Cambrian being placed at the *Olenellus* fauna.³ Here the matter must rest until we can find fossils in the rocks, or verify the organic character of Emmons, *Paleotrochis*; or until we can trace the rocks into a terrane of known age. So also the pyroclastic volcanics must be looked upon as pre-Cambrian.

It is of interest to note that here, as in other portions of eastern North America, the ancient volcanics occur in close proximity to the western edge of the Jura-Trias basin. Adopting Suess' theory of the formation of mountains, we may look upon this central belt of sheared and faulted slates as the levelled site of an ancient Atlantic mountain range; while the bordering Jura-Trias represents a transgression formed by the sunken block on the east; and the early phases of this subsidence were accompanied by the exhibition of volcanic forces.

¹U. S. Geological Survey. Bull. 81. Correlation Papers: by C. D. Walcott; 1891, p. 243.

²Ibid, p. 113.

³U. S. Geological Survey. Bull. 86. Correlation Papers: Archean-Algonkian; p. 495.

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NOTES ON THE NATURAL HISTORY OF THE
WILMINGTON REGION.

H. V. WILSON.

A brief collecting trip to the vicinity of Wilmington, N. C., made about the middle of April, greatly impressed me with the natural history advantages of the region. I publish these few notes in the hope that they may be of service to other naturalists who think of visiting the Southern coast.

In Wilmington itself no one can fail to notice the admirable shade tree, the laurel oak (*Quercus laurifolia* Michx.), so common along the streets. This tree in Wilmington passes under the name of water oak; in South Carolina it is known as the Darlington oak. Its straight bole, symmetrical top and moderate size give it an elegance of shape well suited to city streets, and the impression of finish is heightened by the glossy aspect of the foliage.

From the city there runs a most excellent road, eight miles long, to Wrightsville, a settlement on the coast. The road is a well kept shell road, smooth, hard, and good for bicycling. Scrub oaks, elms, long-leaf pines and cypresses edge it, and near the sound the full green heads of the live oaks are seen on all sides. In the open

meadow-like places (savannahs) to the right and left of the road there grow in great abundance insectivorous plants, the most interesting members, to the general biologist at least, of that rich Wilmington flora made known through the labors of Curtis, Wood and other systematic botanists. The yellow-flowered pitcher plant, *Sarracenia flava*, dots the savannahs in all directions; its great flower (four inches wide) upheld by a scape one to two feet, making it a conspicuous object. The fly-trap, *Dionæa*, and sun-dew, *Drosera*, neither in flower at the time of my visit, are scattered thickly about. Intermingled with these are a blue and yellow species of butterwort, *Pinguicula*, their bright flowers standing out clearly against the at this time brownish savannah and often leading one to patches of *Dionæa* and *Drosera*, which otherwise would have been passed by unnoticed. These five insectivorous plants may sometimes be found growing together in a little patch of ground, scarcely larger than a square foot.

The topography of the Wrightsville district is that characteristic of the Carolina coast, and in a less degree of the Southern coast in general. A sound separates the mainland from a seaward strip of land, known as the 'banks.' Wrightsville, largely made up of houses occupied only during the summer, is on the mainland. Opposite it, on the banks, is a newer summer settlement. Between the two, the sound is crossed by a railroad trestle, the piles of which afford good collecting.

The sound something less than two miles wide, is divided into a narrow outer portion, adjoining the banks and known as the banks channel, and a wider inner portion, studded with sandy-mud shoals. The banks channel is a narrow but pretty boating ground, opening out to sea through two inlets, one recently made in a heavy storm. Along the inner edge of the channel lie some islands, the 'hammocks,' wooded with live oaks, about

which jacksdaws (*Quiscalus major*) were flying. This bird is said to spend the winter here.

At high water one can sail over many of the shoals of the inner part of the sound, but at low water the course from the mainland to the banks channel is a meandering one. The shoals are alive with worms, *Arenicola*, *Dioptatra*, *Clymenella* and other annelids, along with the great *Balanoglossus*, were dug up in quick succession. The reddish egg masses of *Arenicola* lay about in abundance on the flats. The low water collecting in the shoal part of the sound is very easy. Pushing along in a skiff through the shallow channels between the flats, one finds starfish (*Asterias*), the red and white sea-urchins (*Arbacia* and *Toxopneustes*), abundant crabs and other common bottom forms. Scattered about over the bottom in great numbers is the interesting anemone, *Cerianthus americanus*. The tubes that were dug up were something over a foot in length; they contained animals, which of course had greatly contracted, about six inches long. This distinctively Southern actinia, originally found on the South Carolina coast by Professor Louis Agassiz (Verrill, Revision of the Polypi of E. Coast of U. S., p. 32. Mem. Boston Soc. Nat. Hist., Vol. I.), has been observed by Mr. Wm. Stimpson and Professor McMurrich at Beaufort, N. C., where I have seen it myself. It is, however, far more abundant at Wrightsville, and any one wishing to work out the life-history of this remarkable form could find no better locality than the latter place. I may add that the reproductive organs of the specimens I collected were very small. The breeding season probably comes on later.

Just before high water I towed in the neighborhood of the old inlet. As I had anticipated from previous experiences in Beaufort harbor at this time of year, not much of interest was in the water. Small hydromedusæ, crustacean larvæ, abundant *Sagittas*, make up the tow stuff. Later in the year, doubtless as at Beaufort, the towing is

excellent. I am told that abundant large jelly-fish and Portuguese men-of-war make their appearance in August and September.

The sea-beach has a very gentle slope, and judging in part from specimens sent me by Mr. Chas. M. Whitlock, of Wilmington, many things of interest are to be had just beyond the line of breakers, where the sea is frequently calm enough to permit collecting. In the main the Wrightsville fauna is evidently very similar to that of Beaufort see the lists in Studies of Biol. Lab. Johns Hopkins Univ., Vol. IV., No. 2, and the list of annelids by Professor Andrews, Proc. U. S. Nat. Mus. Vol. XIV., No. 852. I may add that some of the local collectors would recognize, from a description, many of the striking forms, such as *Chætopterus*, *Chalina arbuscula*, *Leptogorgia virgulata*, all of which may be had here.¹

¹ From *Science N. S.*, Vol. VI. No. 135. July 30, 1897.

(CONTRIBUTIONS TO THE CHEMISTRY OF ZIRCONIUM. No. 6.)

THE OXALATES OF ZIRCONIUM.

BY F. P. VENABLE AND CHARLES BASKERVILLE.

The text-books of chemistry make either very little or no reference to the oxalates of zirconium. Beyond an occasional reference to the oxalate or basic oxalate gotten by precipitating oxalic acid or an oxalate, we can find little mention of these compounds. Behrens, in his micro-chemical work, speaks of an oxalate prepared as colorless pyramids by precipitating a solution of zirconium sulphate with potassium binoxalate, but no analyses are given, and the crystals could scarcely have been the pure oxalate. Paykull¹ speaks of double oxalates being prepared with

the alkaline oxalates (1:2) and of his failure to prepare the neutral oxalate. His methods, and indeed full results, are unknown to us, as we did not have access to the original paper.

We may summarize the work which follows in the succeeding pages by saying that we found it possible to prepare the basic oxalates by precipitation. This was usually in the form of $\text{Zr}(\text{C}_2\text{O}_4)_{1/2}$, $\text{Zr}(\text{OH})_4$, though other ratios were gotten. The neutral oxalate we did not succeed in preparing, but instead the tendency seems to be toward the formation of the acid oxalate, $\text{Zr}(\text{C}_2\text{O}_4)_{1/2} \cdot \text{H}_2\text{C}_2\text{O}_4 \cdot 8\text{H}_2\text{O}$. This tendency toward the formation of acid salts was shown also in the double oxalates. Two of these were prepared. For sodium, $\text{Zr}(\text{C}_2\text{O}_4)_{1/2} \cdot 3\text{Na}_2\text{C}_2\text{O}_4 \cdot \text{H}_2\text{C}_2\text{O}_4 \cdot 5\text{H}_2\text{O}$, and for potassium the salt $[\text{Zr}(\text{C}_2\text{O}_4)_{1/2}]_2 \cdot (\text{K}_2\text{C}_2\text{O}_4)_2 \cdot \text{H}_2\text{C}_2\text{O}_4 \cdot 8\text{H}_2\text{O}$. The oxalate with ammonium as a constituent was not so easy of preparation in a pure state. The compound secured was $\text{Zr}(\text{C}_2\text{O}_4)_{1/2} \cdot 2(\text{NH}_4)_2\text{C}_2\text{O}_4$. The experiments and analyses are given in detail.

ZIRCONIUM OXALATES.

The Oxalate Gotten by Precipitation.—On the addition of a saturated solution of oxalic acid to a slightly acid solution of zirconium chloride until no further precipitation occurred, a gelatinuous precipitate formed which had very nearly the composition $\text{Zr}(\text{C}_2\text{O}_4)_{1/2} \cdot 2\text{Zr}(\text{OH})_4$. Analysis I gave Zr, 46.39, and C_2O_4 , 30.89, instead of the theoretical 46.40 and 30.93 respectively. The filtrate from this was turbid, and on standing yielded another precipitate which had nearly the composition $2\text{Zr}(\text{C}_2\text{O}_4)_{1/2} \cdot 3\text{Zr}(\text{OH})_4$.

The basic oxalates are very difficultly soluble in acids, and of extremely fine subdivision, settling slowly and passing through even the best filters. It does not seem probable that they could be secured of very constant com-

position. Probably basic oxalates with many different ratios between the oxalate and the hydroxide might be secured. On drying at 100° , or even a little lower, the oxalic acid is gradually volatilized and lost. This is true of all the oxalates and double oxalates prepared so that the only mode of drying these preparations was between filter paper.

The Acid Oxalate Prepared by Crystallization.—In preparing this oxalate, zirconium hydroxide was dissolved in oxalic acid. The hydroxide is quite soluble in oxalic acid, and a concentrated solution is readily obtained. A considerable excess of the acid is required to hold the oxalate thus formed in solution. If this solution be acidified by means of hydrochloric acid a very fine precipitate is obtained settling very slowly, easily passing through the best filter papers and insoluble even in a considerable excess of the acid, but soluble in concentrated sulphuric acid. This precipitate was not analyzed, nor were the exact conditions of its formation determined, as its examination did not promise results of sufficient importance to justify overcoming the difficulties in the way.

On evaporating the acid solution of the oxalate the excess of oxalic acid first crystallized out. In the various preparations made, the first one or two crops of long crystals were found to be nearly pure oxalic acid, and were rejected. Then the form of the crystals changed to small granular or prismatic masses, and with each succeeding crop of crystals the percentage of zirconium increased, reaching speedily an approximately constant ratio. No difference in the form of the crystals in these different crops could be detected on superficial examination, and hence it was impossible to distinguish between the zirconium oxalate and the oxalic acid almost free of zirconium, except by analysis. In no case was the normal oxalate secured. The analyses showed a tendency toward the formation of an acid oxalate and to mixtures of this with the normal oxalate. These mixtures were gotten in the later crys-

tallizations, but the last crystallization, when nearly the whole would solidify into a crystalline mass, showed decreased percentages of zirconium. It is possible that larger amounts than we had at our disposal would enable one to so fraction the crystallizations as to secure a pure oxalate. It is, however questionable whether the normal oxalate can exist in solution without admixture with some oxalic acid.

Four series of crystallizations were made, and in two cases fairly abundant crops of crystals corresponding to the acid oxalate were obtained. In each series enough of the zirconium hydroxide was taken to form about twenty grams of the oxalate.

| | First series. Sixth fraction. | Second series. Fifth fraction. | |
|------------------------------|----------------------------------|-----------------------------------|---|
| | II. | III. | $\text{Zr}_2\text{C}_2\text{O}_4 \cdot 2\text{H}_2\text{C}_2\text{O}_4$ |
| Zr | 25.44 | 25.28 | 25.53 |
| C_2O_4 | 74.55 | 74.72 | 74.47 |

These are calculated upon the water-free basis. The crystals contained 29.34 and 29.27 per cent. of water respectively, where the salt $\text{Zr}_2\text{C}_2\text{O}_4 \cdot 2\text{H}_2\text{C}_2\text{O}_4 \cdot 8\text{H}_2\text{O}$ contains 28.90 per cent. Other crops of crystals contained percentages of zirconium not varying greatly from those given above as 28.14, 27.62, 24.9, 23.83. The percentage of zirconium in the normal oxalate is 33.96.

ZIRCONIUM SODIUM OXALATE.

The addition of sodium oxalate to a slightly acid solution of zirconium chloride gives a gelatinous white precipitate. Most of this dissolves in an excess of the oxalate. The undissolved portion settles to the bottom, and after prolonged standing, a second layer of a more powdery appearance forms. This can also be gotten by concentration of the filtrate from the first precipitate. Analysis showed that the first gelatinous precipitate was chiefly $\text{Zr}(\text{OH})_4$. The second precipitate was a double oxalate of zirconium and sodium, but was either of incon-

stant composition (varying ratios of sodium to the zirconium), or was decomposed by the washing.

The analyses, calculated on a dry basis, gave:

| | IV. | V. | VI. |
|-------------------------------------|-------|-------|-------|
| Zr..... | 53.12 | 46.86 | 41.98 |
| Na | 9.16 | 4.10 | 1.07 |
| C ₂ O ₂ | 38.06 | 39.64 | 42.95 |

If the solution made with the excess of the sodium oxalate was diluted considerably with water, a gelatinous precipitate was formed, very fine and insoluble. Precipitates were also formed by the addition of hydrochloric acid. This mode of forming the double oxalate was abandoned, and the following method was adopted with greater success. Zirconium hydroxide was dissolved in an excess of oxalic acid, and to this a concentrated solution of sodium hydroxide was added, bringing it nearly to neutralization. When the solution was concentrated an abundant crop of crystals was obtained on cooling, a good deal of heat being evolved in the mixing. Further evaporation yielded other crops of crystals. These were washed, dried between filter paper and analyzed. The results are given in the following table:

| | VII. | VIII. | IX. | Calculated. |
|-------------------------------------|-------|-------|-------|-------------|
| Na | 18.14 | 17.46 | 17.75 | 18.19 |
| Zr | 12.59 | 12.66 | 12.78 | 11.93 |
| C ₂ O ₄ | 69.27 | 66.89 | 69.47 | 69.88 |

These results show a somewhat wide variation from those calculated. This probably arises from the fact that the fractions were not composed of the crystals of a single kind of oxalate, but had other oxalates mixed with them in small amounts. Examined under a magnifying glass they seemed to be homogeneous, but the different crops could not be distinguished from one another. They were all small, hard prismatic crystals, somewhat difficultly soluble in water. One set of crystals, the analysis of which is reported under VII in the above table, was

redissolved in water and recrystallized. On analysis it yielded the following results:

| | VII. | IX. |
|-------------------------------------|-------|-------|
| Na..... | 18.14 | 18.19 |
| Zr..... | 12.59 | 12.71 |
| C ₂ O ₄ | 69.27 | 69.10 |

These were calculated upon a water-free basis. The crystals from the various crops mentioned above did not contain a very constant amount of water, but ranged from 9.13 to 11.06. The calculated amount of water in Zr (C₂O₄)₂.3Na₂C₂O₄.5H₂O is 10.62. It would seem, therefore, that the tendency, when this method of formation is adopted, is toward the formation of crystals containing free oxalic acid and with the sodium and zirconium oxalates bearing a ratio of three to one.

ZIRCONIUM POTASSIUM OXALATE

The curdy precipitate gotten by precipitating zirconium chloride with normal potassium oxalate is insoluble in an excess of either of the substances. The precipitate first obtained is an impure zirconium hydroxide, containing only small amounts of oxalic acid. The supernatant liquid on concentration yields needle-like crystals of potassium oxalate, carrying only traces of zirconium. After the separation of a good deal of this potassium oxalate, further concentration yielded a gelatinous substance having the composition (XII): Zr, 39.34; K, 5.06; C₂O₄, 43.05; which seems to be a basic zirconium oxalate, mixed or united with a small proportion of potassium oxalate. If the potassium be calculated as potassium oxalate and subtracted, the composition of the remainder would be approximately Zr (OH)₄. Zr(C₂O₄)₂.

On adding potassium binoxalate to a solution of zirconium chloride a white curdy precipitate was obtained which was not completely soluble in excess of the binoxalate. The somewhat turbid solution was filtered and evaporated. Large crystals resembling those of oxalic acid formed. These were separated, and on analysis proved

to be oxalic acid. At the same time a number of small crystals were formed, which were mechanically separated, washed and dried. These were analyzed and are reported under XIII. A further crop was gotten from the mother liquor, and the analysis is given under XIV.

| | XIII. | XIV. |
|-------------------------------------|-------|-------|
| Zr..... | 19.59 | 17.99 |
| K..... | 16.18 | 13.91 |
| C ₂ O ₄ | 64.23 | 68.09 |

The curdy precipitate, which first formed, was also examined and found to have the composition $\text{Zr}(\text{C}_2\text{O}_4)_2 \cdot 2\text{Zr}(\text{OH})_4$.

The addition of a solution of potassium tetroxalate to zirconium chloride gave a gelatinous precipitate of zirconium oxalate (basic), carrying a little potassium oxalate. Subtracting the potassium oxalate, the percentages (XVI) Zr, 39.09 and C₂O₄, 38.63 are left, which are not very different from the figures gotten for the precipitate from potassium oxalate (neutral).

This curdy gelatinous precipitate was dissolved in excess of tetroxalate and the solution placed over sulphuric acid to crystallize, and yielded crystals having the composition (XVII): Zr, 20.85; K, 16.72; and C₂O₄, 62.31. As will be seen, these are not far from the 1:2 zirconium potassium oxalate, with excess of oxalic acid.

When potassium hydroxide was added to a solution of zirconium oxalate in oxalic acid until nearly neutral and then set aside for crystallization, various crops of crystals were gotten, as in the case of the double sodium oxalates. These crops of crystals were similar in appearance to the sodium crystals. They were analyzed and showed fairly constant composition.

| | XVIII. | XIX. | XX. | XXI. | (Zr(C ₂ O ₄) ₂) ₂ · (K ₂ C ₂ O ₄) ₂ · H ₂ C ₂ O ₄ · |
|-------------------------------------|--------|-------|-------|-------|--|
| Zr..... | 18.08 | 19.25 | 19.83 | 18.47 | 18.95 |
| K..... | 16.41 | 16.35 | 14.84 | 14.46 | 16.34 |
| C ₂ O ₄ | 66.51 | 64.40 | 65.33 | 67.07 | 64.71 |

The three previous analyses may also be referred to

here as having approximately the same composition. See analyses XIII, XIV, XVII. These are calculated as water-free. In the analyses XVIII and XIX the percentages of water were 12.99 and 12.38. These would correspond to the formula $(\text{Zr}(\text{C}_2\text{O}_4)_{1.2})_{0.7} \cdot \text{K}_2\text{C}_2\text{O}_4 \cdot 11.2\text{H}_2\text{C}_2\text{O}_4 \cdot 8\text{H}_2\text{O}$. In this case, as in the zirconium oxalates and the sodium oxalates, the crystals seem to form only along with free oxalic acid, giving acid salts.

ZIRCONIUM AMMONIUM OXALATES.

The addition of a solution of ammonium oxalate to the slightly acid solution of zirconium chloride gave a heavy gelatinous precipitate which was soluble in excess of ammonium oxalate and proved to be zirconium hydroxide with more or less zirconium oxalate and small amounts of ammonia. The filtrate from this precipitate was evaporated slowly and a fine crystalline powder obtained. This contained (XXII) Zr, 42.17 per cent. and C_2O_4 , 39.86 per cent. This is in fair agreement with $\text{Zr}(\text{C}_2\text{O}_4)_2 \cdot \text{Zr}(\text{OH})_4$. When ammonium oxalate is added until the first gelatinous precipitate is redissolved and then evaporated to crystallization, different crops of crystals can be gotten containing various amounts of ammonia. These did not seem to have any regular composition in our experiments and were looked upon as basic zirconium oxalates with varying amounts of ammonium oxalate present. Thus for one of these the figures (XVIII) Zr, 31.48; NH_3 , 7.14; and C_2O_4 , 61.38 were gotten.

Abandoning this method and using the one adopted in the cases of the sodium and potassium double oxalates, a more favorable result was obtained. Zirconium hydroxide was dissolved in excess of oxalic acid and then this was nearly neutralized by means of ammonium hydroxide. Analyses of these crops of crystals follow:

| | XXIV. | XXV. | $\text{Zr}(\text{C}_2\text{O}_4)_2 \cdot 2 \text{NH}_4 \cdot \frac{1}{2} \text{C}_2\text{O}_4$. |
|------------------------------|-------|-------|--|
| Zr..... | 16.55 | 16.66 | 17.58 |
| NH_3 | 14.46 | 13.35 | 13.28 |
| C_2O_4 | 69.99 | 69.99 | 68.94 |

While these do not show that the crystals had been thoroughly purified, the results indicate that the composition is one zirconium oxalate to two ammonium oxalate. On recrystallizing one of these crops of crystals, zirconium hydroxide was observed to separate when the solution was heated (to evaporate to crystallization), and the crystals which were obtained consisted of ammonium oxalate alone.

In general it may be stated that the zirconium oxalate fails to show any decided tendency to enter into clearly defined combinations with the alkaline oxalates, exhibiting rather a power of crystallizing along with them in mixtures of any proportions. It can be said at best that under the conditions of our experiments certain ratios seem to be preferred, and appeared more persistently. In all cases the crystals formed from oxalic acid solutions, and this free oxalic acid crystallized with them, giving acid oxalates.

THE HALOGEN SALTS OF ZIRCONIUM.

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I. DECOMPOSITION OF THE ZIRCONS.

It may be well to give in detail the method (Jour. An. and Ap. Chem. 1891.551) as modified by an experience of several years. The zircons are ground in an iron mortar so as to pass a 90 mesh sieve. The proportions used in a fusion are 150 grams zircons, 400 grams sodium hydroxide 40 grams sodium fluoride. The sodium hydroxide and fluoride are fused in a nickel crucible (400 cc) then heated for fifteen or twenty minutes with the water blast

The zircons are introduced in portions of five or six grams. If the temperature is high enough there is a rapid evolution of bubbles of gas. It must be stirred to prevent foaming over (the stirrer being a strip of nickel fastened to a glass rod.) After the introduction of three-fourths of the zircon the temperature should be increased by adding other lamps as the mass becomes pasty and sluggish towards the close of the reaction, making the escape of bubbles somewhat explosive. The success of the operation depends on the high temperature, especially at the close. With a lower temperature much will be left unacted upon. After the introduction of all the zircon the mass should be heated and stirred until no more bubbles escape. This stirring can only be imperfectly carried out towards the close. The mass should then be immediately removed by means of a nickel spatula and the lumpy pieces allowed to cool on crucible tops or sheets of nickel. The crucible should be scraped as clean as possible before cooling. It is best then to quench it with water before the adhering pieces of the melted mass cool, and crack the crucible in contracting. A number of crucibles crack during the fusion. If they escape this they almost infallibly crack in the cooling unless cooled down filled to the brim with water. Of course due care must be taken in introducing the water. It can be safely blown in from a distance with a wash bottle. As there is much spitting of melted caustic soda during the fusion the hands should be gloved and the handle of the stirrer should be long enough to secure the face and eyes from danger.

The lumps, while still hot, are removed from the nickel sheet and placed in water in a casserole (1 litre capacity). After a few minutes the water becomes muddy on agitation. Pour off this water with the suspended particles into a large settling jar. Refill the casserole, heat to boiling, stir and pour off again, thus removing gradually the finer masses. This is the best way of disintegrating

and washing the mass. The particles settle best from hot water. After a while they settle slowly. It is best to use two or three settling jars, pouring off from the first to the others before a second washing is added from the casserole. Nearly all settles in the first jar and that which settles more slowly may be allowed to take its time in the other jars. After a while the disintegration may be helped by breaking with a glass rod or rubbing with a pestle. Five or six gallons of water should be used in washing as this removes the sodium silicate and it is far easier and better to get rid of it in this way than to be worried by its presence later on. Of course it is not entirely removed and some little of the zirconate is also lost.

After washing the sodium zirconate must be decomposed by the addition of hydrochloric acid. Strong acid is used and it is boiled with the zirconate in the casserole used for washing. Usually all dissolves up except a few grams of undecomposed zircon. It is not necessary to filter the solution. It may be immediately transferred to a large evaporating dish and carried down to dryness, first over the naked flame and then, as silica etc., begin to separate out, on the sandbath. It is necessary to watch the temperature of the latter and to stir the mass up occasionally to prevent overheating but a great deal of time may thus be saved. It is usually possible to begin a fusion in the morning and have the hydrochloric acid solution of it ready for evaporation before the day's work is over.

If the washing was well done the amount of silica separating is not large. Hydrochloric acid is added to the dried mass, then water and it is filtered. The clear filtrate is again evaporated to dryness to remove the last traces of silica. We have uniformly adopted this precaution but seldom found any silica separated by the last evaporation. After this second evaporation and filtration the solution is ready for the separation of the iron.

The larger portion of the iron may be separated by the use of sulphur dioxide. The impure zirconium chloride is made up into a moderately dilute solution in a large jar. This is nearly neutralized with ammonia and sulphur dioxide is passed through. The zirconium is precipitated out as a basic sulphite. This is filtered away from the solution containing most of the iron. In most cases it is advisable to dissolve again in hydrochloric acid and precipitate once more with sulphur dioxide. The filtrate containing the iron also contains much of the zirconium. A good deal of this is precipitated on boiling. The filtrate from this is then evaporated to a small bulk and a good deal of the iron will crystallize out as the double chloride of iron and ammonium in deep red crystals. The concentrated filtrates from several fusions, thus partly freed from iron, may be again treated with sulphur dioxide and the zirconium recovered.

The sulphite after draining in large funnels is dissolved in hydrochloric acid and boiled until all sulphur dioxide is driven off. It is then precipitated as hydroxide by means of ammonium hydroxide and well washed. This hydroxide is drained upon filters and dissolved in the least amount of concentrated hydrochloric acid. The remaining impurities are gotten rid of by repeated crystallizations from strong hydrochloric acid. This must be managed with some care as it is quite easy to form an oxychloride insoluble in the strong acid, for instance by the addition of strong acid to a somewhat concentrated aqueous solution. In evaporating the hydrochloric acid solution to crystallization it is therefore necessary to add concentrated acid from time to time as the watery acid evaporates so that the first crystallization shall be from strong acid. After that there is little trouble in subsequent crystallizations from strong acid. The crystallizations are best made from a casserole and one hundred grams or more of chloride may be crystallized at a time. Generally twelve or fifteen crystallizations will

suffice. There will be little loss of zirconium if just enough acid is used each time to bring the soluble chloride into solution (some little insoluble chloride is nearly always present.) The acid poured off each time from the crystals may be saved and evaporated to recover the zirconium or used in the decomposition of other portions of zircons.

II. ZIRCONIUM CHLORIDES.

Large number of compounds of zirconium with chlorine or chlorine and oxygen have been described and these compounds have been the subject of much investigation. The object in many cases has been to secure a zirconium chloride of definite composition which would prove a valuable compound for determining the atomic weight of the element. There are several difficulties in the way of securing such a compound.

1. The tendency to form basic chlorides.
2. The ease with which hydrochloric acid is lost through the action of heat and of dehydrating agents.
3. The presence of free hydrochloric acid.
4. The deliquescent nature of the chlorides.

It is particularly desirable that the conditions under which a definite chloride can be formed should be discovered, as zirconium seems to yield no very satisfactory compounds for the determination of the atomic weight. There have been many efforts at finding out these exact conditions.

Most text-books state that anhydrous, pure zirconium tetrachloride can be prepared by passing dry chlorine over a mixture of charcoal and zirconia heated to a high temperature. Hermann used this sublimed zirconium chloride for the determination of the atomic weight. As Clarke says, however, little confidence can be placed in his results. Bailey (*Chem. News.*, 60, 17.) has recorded that even with great care to avoid the presence of moisture he was unable to prevent the formation of oxychloro-

rides. He also says that in no case was it found possible to prepare the chloride free from iron and silica. The necessity for the presence of these in the materials used or in the resulting compound is not very apparent. We have as yet had no opportunity of repeating his experiments.

This tetrachloride has also been prepared by passing dry chlorine over zirconium or over zirconia and charcoal.

Troost and Hautefeuille [Compt. rend, LXXV., 1889.] have prepared it by the action of silicon chloride upon zirconia. Smith and Harris [Am. Chem. Soc. 1895. 654] succeeded in preparing this same chloride by heating zirconia with phosphorus pentachloride.

The chlorides most commonly worked with, have been those formed by the solution of the hydroxide in hydrochloric acid, followed by precipitation or crystallization from concentrated hydrochloric acid or from water.

Berzelius attempted to remove the excess of hydrochloric acid by heating the salt to 60°C . but was not able to obtain a definite compound.

Two analyses gave

| | | |
|------------------------|-------|-------|
| ZrO ₂ | 0.332 | 0.485 |
| AgCl..... | 0.661 | 1.096 |

The silver chloride should be about two and one-third times as much as the oxide.

Paykull dried the salt between filter paper and found the composition of the crystals to be $\text{ZrOCl}_2 \cdot 8\text{H}_2\text{O}$. According to Melliss Zeitschr. f. Chem. [2], VI. 196 this salt crystallizes with $4\frac{1}{2}\text{H}_2\text{O}$ instead of $8\text{H}_2\text{O}$. The amorphous form is precipitated by pouring the aqueous solution into strong hydrochloric acid. This is insoluble in boiling concentrated acid but easily soluble in water. Paykull Ber. VI. 1467 assigns to this the formula $2\text{ZrOCl}_2 \cdot 13\text{H}_2\text{O}$.

Endemann has described basic or oxychlorides $\text{Zr}_3\text{O}_7\text{Cl}_2$, ZrOCl_2OH , and $\text{Zr}_2\text{O}_5\text{Cl}_2 \cdot \text{OH}$; Troost and Hautefeuille have described others, $\text{Zr}_2\text{O}_3\text{Cl}_2$ and Zr_2OCl_6 . In fact water is so easily taken up and hydrochloric acid lost

that a large number of such indefinite compounds might be prepared by slightly varying the conditions.

Nylander (*Bidrag till kännedom om Zirkonjord* Inaug. Diss. Lund 1864.) made a series of attempts at dehydrating the chloride. He prepared the chloride by dissolving the hydroxide in hydrochloric acid and evaporating to crystallization. The salt formed white needles, easily soluble in water. They were washed with alcohol and for analyses I and II were pressed between filter paper; III and IV were dried over sulphuric acid. The results were as follows:

| | I. | II. | III. | IV. |
|-----------------------------|-------|-------|-------|-------|
| Zr..... | 27.56 | 25.69 | 30.11 | 31.78 |
| Cl..... | 21.58 | 21.58 | 23.06 | 23.80 |
| Loss(H ₂ O)..... | 50.86 | 52.78 | 46.83 | 44.12 |

or calculated on a dry basis:

| | | | | |
|---------|-------|-------|-------|-------|
| Zr..... | 56.08 | 54.41 | 56.63 | 57.18 |
| Cl..... | 43.02 | 45.59 | 43.37 | 42.82 |

Again preparations were made as before. I was dried between filter paper, II over sulphuric acid, III was pressed between filter paper and then dried over sulphuric acid, IV was dried a long time over sulphuric acid. The analyses gave the following:

| | I. | II. | III. | IV. |
|-----------|-------|-------|-------|-------|
| Zr..... | 28.52 | 34.91 | 37.78 | 35.69 |
| Cl..... | 21.93 | 26.09 | 25.87 | 21.74 |
| Loss..... | 49.55 | 39.10 | 36.35 | 42.57 |

or calculated on a dry basis:

| | | | | |
|---------|-------|-------|-------|-------|
| Zr..... | 56.93 | 57.23 | 59.34 | 62.14 |
| Cl..... | 43.07 | 42.77 | 40.66 | 37.86 |

Lastly he allowed a solution of the chloride to evaporate over sulphuric acid washed the crystals obtained with alcohol and pressed them between filter paper. Analyses gave:

| | | |
|-----------|-------|-------|
| Zr..... | 27.94 | 28.74 |
| Cl..... | 27.32 | 26.67 |
| Loss..... | 44.74 | 42.62 |

or calculated on a dry basis:

| — Found — | | Theory. |
|-----------------------|-------|---------|
| Zr..... | 50.56 | 50.04 |
| Cl..... | 49.44 | 49.96 |
| Zr..... | | 38.50 |
| Cl ₄ | | 61.50 |

Nylander's description of this salt is correct. Very large handsome crystals can be secured on evaporating an aqueous solution of the chloride prepared by dissolving the hydroxide in hydrochloric acid. If this evaporation is too rapid gelatinous masses separate out, re-dissolving on stirring. There is a considerable loss of hydrochloric acid during this evaporation. The best crystals may be obtained by evaporation over sulphuric acid. These crystals easily dry on porous plates or on filter paper. There is no necessity for the elaborate methods of drying adopted by Nylander. There is however a constant though slight loss of hydrochloric acid. Nylander's analyses (marked I) agree very closely with one made by us.

| | |
|-----------|-------|
| Zr..... | 28.05 |
| Cl..... | 21.59 |
| Loss..... | 50.46 |

There is then manifestly a definite compound obtained in this way. It is unquestionably an oxychloride and the loss (50.46 per cent.) represents both water and combined hydroxyl or oxygen. At ordinary temperatures there is a continuous loss from day to day which makes it impossible to get a fixed initial weight. This loss is shown by the following weighings.

| | | | | | | |
|-----------|---------|----------|----------|----------|----------|----------|
| Date | Oct. 9. | Oct. 11. | Oct. 12. | Oct. 13. | Oct. 15. | Oct. 18. |
| Weighings | 1.2806 | 1.2796 | 1.2792 | 1.2787 | 1.2779 | 1.2758 |

By heating to 135° - 140° for six hours a large amount of chlorine is driven off and yet not all of the water. The mass left is insoluble. Heated to 100° under a stream of hydrogen chloride the weight was constant and the loss corresponded to 26.84 per cent. of the original weight. The residue is entirely soluble in water. While these data are not altogether sufficient it will be seen that they correspond fairly accurately with the formula $\text{ZrOCl}_2 \cdot 8\text{H}_2\text{O}$. Five molecules of water are lost at 100° and the compound left is $\text{ZrOCl}_2 \cdot 3\text{H}_2\text{O}$. The first formula is the formula assigned by Paykull and confirms his results as against those of Melliss. The formula gotten by Herrmann, $\text{ZrOCl}_2 \cdot 9\text{H}_2\text{O}$ was manifestly obtained from imperfectly dried crystals.

Bailey repeatedly crystallized the chloride from hydrochloric acid, washed it with hydrochloric acid and then removed the free acid.

(1) By washing with a mixture of one part alcohol and ten parts of ether.

(2) By gently heating the salt.

(3) By exposing the finely divided salt at ordinary temperatures in a vacuum desiccator over potash until no hydrochloric acid appeared when air was passed over it.

The analysis was performed by dissolving the salt in water and precipitating the zirconia with ammonia, then acidulating with nitric acid and precipitating the chlorine by means of silver nitrate. By method (2) a constant and progressive diminution of chlorine was observed. Therefore no analyses were made. For the other methods he gives the results of the analyses by a statement of the relation of ZrO_2 to AgCl .

| | ZrO_2 : | AgCl |
|-------------------------------|------------------|---------------|
| Berzelius determination | 1 | : 1.991 |
| " " | 1 | : 2.260 |
| Bailey's method 1 | 1 | : 2.206 |
| " " " | 1 | : 2.179 |
| " " " | 1 | : 2.226 |
| " " " | 1 | : 2.260 |
| " " 2 | 1 | : 2.264 |
| " " " without washing | 1 | : 2.245 |
| " " " | 1 | : 2.309 |
| " " " | 1 | : 2.285 |
| ZrOCl_2 | 1 | : 2.350 |

In all of these the drying has gone too far and some of the chlorine has been lost or the crystals still retained hygroscopic moisture. This salt, as will be seen later on, is not ZrOCl_2 but $\text{ZrOCl}_2 \cdot 3\text{H}_2\text{O}$ and the true ratio is ZrO_2 : AgCl :: 1 : 2.327.

Hermann (Watts' Dict., 5, 1080.) states that the hydrated chloride, gotten in crystals on evaporating its aqueous solution, becomes opaque at 50°C ., giving off part of the water and half of the hydrochloric acid and leaving a basic chloride or oxychloride, $\text{ZrCl}_4 \cdot \text{ZrO}_2 \cdot 18\text{H}_2\text{O}$ or $\text{ZrOCl}_2 \cdot 9\text{H}_2\text{O}$. The same compound is obtained in stellate groups of

white silky prisms on evaporating a solution of the chloride. These crystals when heated become white and turbid and are converted into the anhydrous dioxychloride, $\text{ZrCl}_4 \cdot 2\text{ZrO}_2$.

Linnemann (Chem. News., LII, 224.) maintains that crystallization from hydrochloric acid (sp. gr. 1.17) and treatment with alcohol and ether gives a fine, crystalline, snow white, silky body; leaving fifty per cent. of its weight on ignition and therefore very nearly pure ZrCl_4 which should leave 52.5 per cent. He claims that this is "chiefly a neutral, not a basic compound."

Our own experiments on the dehydration of the salt obtained by crystallization from water extended over two years, as opportunity was afforded. Several series of experiments were undertaken, some along the lines attempted by others, and others by methods not tried before. In all the purified chloride obtained by repeated crystallization from hydrochloric acid was used, the salt being still wet with the excess of the acid. There was no attempt at drying this between filter paper.

In the first experiment this chloride was washed once with water and then put in a desiccator and dried over calcium chloride porous desiccated. It remained in the desiccator about seven months. Even after this lapse of time it still continued to show a slight loss in weight. It yielded on analysis 48.84 per cent. ZrO_2 .

Another portion was placed in a jar over solid lumps of sodium hydroxide. After six weeks the loss was very slight. Careful ignition left a residue of ZrO_2 equivalent to 42.99 per cent. of the original weight. There was found to be 24.44 per cent. of chlorine present.

Again a portion was placed over calcium chloride and dry air was drawn over it at the rate of about fifty liters in the twenty-four hours for six months. After the first two months it was examined weekly by the interposition of a flask containing silver nitrate to see whether hydrochloric acid was still coming off. Even after the lapse

of so long a time as this it was found that the loss of hydrochloric acid continued, although it was slight. On analysis this gave ZrO 42.28 per cent., and Cl 24.35 per cent. Although the results in this, and the experiment immediately preceding correspond fairly well, they are unsatisfactory as they point either to a mixture of chlorides or an oxychloride of very complicated formula and hence unsuited for the ultimate aim of the research.

Lastly a portion was placed over concentrated sulphuric acid and the atmosphere above it exhausted occasionally. This was kept up during two months of summer weather. The loss in the last fifteen days was about 0.02 per cent. of the whole. The mass was powdery with a slightly discolored crust. It was all soluble in water, however, and yielded a clear colorless solution. It contained 53.30 per cent. of ZrO_2 . This corresponds very nearly to the formula $\text{ZrOCl}_1.3\text{H}_2\text{O}$.

This last experiment showed the possibility of securing pure zirconium chloride, provided the excess of hydrochloric acid could be removed. It was thought that this might be done by heating in an atmosphere of hydrochloric acid. A weighed flask was so arranged that it could be kept at a definite temperature while a stream of dry hydrogen chloride was passing through it. The temperature ranged from 100° to 110°C ., and the chloride placed in the flask melted, solidifying again after the loss of the water and excess of hydrochloric acid. If the drying was done slowly enough, apparently crystalline oxychloride was gotten which lost no further weight on being kept at 100°C . A more rapid drying left a hard white mass quite hygroscopic. Heating this mass for several days did not cause any diminution in weight, provided the flask was kept full of hydrogen chloride. If the mass was heated even a short time in the absence of hydrogen chloride then further heating caused a continuous loss of weight even in the presence of a rapid stream of hydrogen chloride. After this it was impossible to secure a constant weight.

This method of drying has been tried repeatedly on various preparations and I regard the facts stated above as showing conclusively that a neutral zirconium chloride can be prepared and dried.

Analyses of this chloride gave the following percentages of ZrO_2 :

| | | |
|-------|-------|-------|
| 52.70 | 52.78 | 52.63 |
|-------|-------|-------|

Believing that a simple compound of zirconium and chlorine had been obtained corresponding to the formula $ZrCl_4$, a series of determinations were undertaken with a view to securing data for calculating the atomic weight.

This chloride obtained by recrystallization from concentrated hydrochloric acid had also been analyzed by Linnemann (Lond. Chem. News LI, 233-240) and the percentage of zirconium found led him to believe that it was the tetrachloride. The determinations made by one of us with a view to securing data for recalculating the atomic weight were ten in number. They were made with great care and yielded a mean of 52.986. This would have corresponded to an atomic weight of 91.75 if the body were really the tetrachloride. To settle its exact composition the chlorine was determined in a sample dried also in hydrogen chloride. Two determinations gave the mean percentage of chlorine as 35.26. This result is entirely too low for the tetrachloride which would require 61.01 per cent. of chlorine. The substance analyzed was then manifestly an oxychloride but none of simple composition could be calculated from the results. The formula which seemed nearest to it was $Zr_3(OH)_5Cl_7 \cdot 5H_2O$. (see J. Am. Chem. Soc. 1895. p. 842). The subject was then allowed to drop for two years, except that the chloride was tested for water and found to give it off abundantly at 180° – 210° .

During the past summer the accuracy of the chlorine determination was brought into question. Determinations were made on other samples and the percentage of chlorine was found to be 29.98. The error of the previous deter-

mination may have been due to the sample or to manipulation. Which was at fault cannot well be decided now. The new determinations give

| | Calc. for $\text{ZrOCl}_2 \cdot 3\text{H}_2\text{O}$. |
|-----------|--|
| Zr. 38.99 | 39.12 |
| Cl. 29.98 | 30.66 |

This oxychloride is therefore, after drying, identical with the one obtained by crystallization from water after it also has been dried.

The amorphous (?) form, insoluble in concentrated hydrochloric acid but easily soluble in water has been analyzed by Paykull and he has calculated the formula $2\text{ZrOCl}_2 \cdot 13\text{H}_2\text{O}$. This insoluble oxychloride is nearly always present during the process of purification by recrystallization from hydrochloric acid. Repeated boilings with hydrochloric acid fail to dissolve it. A sample was prepared by allowing a very concentrated aqueous solution of the oxychloride to fall drop by drop into concentrated hydrochloric acid. It was washed with hydrochloric acid and then boiled. After pouring off the acid the mass was washed with a mixture of nine parts ether and one part alcohol. It was dried between filter paper. Little assurance could be felt that this mode of drying removed all the hygroscopic moisture. It was analyzed in this condition. Another portion was placed over caustic alkali (after pressing between filter paper, and yet another portion was dried at 105° in a stream of hydrogen chloride.

The analysis of the portion dried between filter paper was as follows: (no difference was observed in that over caustic alkali after two days).

| | Calc. for $\text{ZrOCl}_2 \cdot 6\text{H}_2\text{O}$. |
|-----------|--|
| Zr. 31.72 | 31.70 |
| Cl. 20.81 | 21.01 |

This is therefore in close accord with the formula $\text{ZrOCl}_2 \cdot 6\text{H}_2\text{O}$. The portion dried under hydrogen chloride was small and only the zirconium was determined. The percentage of this corresponded fairly with $\text{ZrOCl}_2 \cdot 3\text{H}_2\text{O}$.

Summarizing our examination of these oxychlorides then, we find that there are three.

1. An oxychloride gotten in large, well-formed crystals by crystallization from water. These crystals lose slowly both water and hydrochloric acid on exposure to the air. Their formula is $\text{ZrOCl}_2 \cdot 8\text{H}_2\text{O}$.

2. An oxychloride gotten by precipitation by hydrochloric acid from an aqueous solution. This is insoluble in hydrochloric acid. It is seen in silky crystals or a white mass of very fine crystals. The formula is $\text{ZrOCl}_2 \cdot 6\text{H}_2\text{O}$.

3. An oxychloride gotten by crystallization from hydrochloric acid. This has the formula $\text{ZrOCl}_2 \cdot 3\text{H}_2\text{O}$.

When any one of these is dried at $100\text{--}125^\circ$ with a stream of dry hydrogen chloride passing over it three molecules of water of crystallization are left and the oxychloride has the formula given under 3. namely $\text{ZrOCl}_2 \cdot 3\text{H}_2\text{O}$. These last molecules of water are lost at a temperature of $180\text{--}210^\circ$.

Weibull (Ber. 1887. 1394) gives the measurements of the crystals of the oxychloride formed from water. They belong to the tetragonal system, are optically uniaxial with double refraction.

Several times during the examination of these oxychlorides the formation of a hydrogele was observed. The exact conditions under which it was formed were not determined. The tendency to form this hydrogele is much less than in the case of the bromides and iodides. Similar compounds will be mentioned there.

III. ZIRCONIUM BROMIDES.

Zirconium tetrabromide, ZrBr_4 , is formed by conducting bromine vapor over a heated mixture of zirconium and carbon. A stream of carbon dioxide may be used for carrying the bromine vapor. It forms a white crystalline (microscopic) powder which can be sublimed but is decomposed by water, (Melliss J. 1870. 328).

Zirconium oxybromide may be formed by decomposing

the tetrabromide with water and also by dissolving zirconium hydroxide in hydrobromic acid (Gmelin, Handbook, 6th ed'n. II. 1. 706.) It crystallizes from the aqueous solution in fine transparent needle like crystals containing water of crystallization (Melliss, Mats Weibull B. 1887. 1394).

Weibull gives the following analyses:

| | | | Calc. $\text{ZrOBr}_2 \cdot 8\text{H}_2\text{O}$ |
|---|----|-------|--|
| - | Zr | 20.35 | 20.83 |
| | Br | 41.16 | 39.05 |

He says that the crystals are isomorphous with those of the oxychloride which seems to be true. They are much more hygroscopic. His two analyses are decidedly discordant and one would judge that the amount of water of crystallization had been decided upon from the analogy to the oxychloride.

The oxy-bromides described in the following experiments belong to two types with varying degrees of hydration— ZrOBr_2 plus $x \text{H}_2\text{O}$, where x equals 3, 13, or 14 and $\text{ZrBr}(\text{OH})_3$ plus $y\text{H}_2\text{O}$ where y equals 1 or 2. All of these compounds are deliquescent and decompose on exposure to moist air, the clear white crystals, often colored pink by free bromine present, melting to a gum, frequently with the evolution of hydrobromic acid. The salts are unstable even in dry air as was found on exposing dried crystals upon a watchglass in a desiccator containing sulphuric acid. Much hydrobromic acid was evolved in the decomposition.

The crystals were prepared in two ways:—either by dissolving pure $\text{Zr}(\text{OH})_4$ in dilute hydrobromic acid evaporated upon water bath with subsequent additions of 48 per cent. hydrobromic acid and repeated evaporations, or a concentrated solution of hydrobromic acid was saturated with $\text{Zr}(\text{OH})_4$, evaporated and the crystals obtained on cooling.

As a rule the crystals obtained were quite soluble in the hot acid but separate at once on cooling. In the heating necessary for the thorough saturation of the hy-

drobromic acid by the $\text{Zr}(\text{OH})_2$, the solution first becomes straw colored then a deeper red depending upon the time of the heating. This is evidently due to bromine from the decomposition of some hydrobromic acid by organic matter in the air.

A difficult problem was the removal of the strong hydrobromic acid mother liquor and the free bromine nearly always present with the crystals. Of the methods tried to effect this none proved satisfactory. The crystalline mass was in one case six times washed with ether, the yellowish red solution, due to dissolved bromine, being decanted. Filtering proved too slow permitting a rather long exposure of the crystals to the moisture of the air. After this washing with ether the crystals still slightly yellow colored were placed in a "vacuum" desiccator for the removal of the remaining ether. The small glass dish containing the material was allowed to remain 36 hours in the vacuum desiccator. The substance was then removed, dried between filter paper and analyzed.

| | Found | | Calc. for $\text{ZrOBr}_2 \cdot 13\frac{1}{2}\text{H}_2\text{O}$ |
|---|-------|----------------|--|
| ZrO_2 | 24.15 | 24.50 24.60 | 24.61 |
| Br | 32.29 | | 31.93 |
| $\text{H}_2\text{O } 124^\circ\text{C}$ | 24.44 | | |

This substance gave evidence of decomposition after being placed in the weighing bottle.

Another method used for the removal of bromine was washing the colored crystals three times with strong (48 per cent.) solution of hydrobromic acid. Most of the bromine was thus removed, although the salt remained slightly yellow, possibly due to the remaining hydrobromic acid. An interruption of the work at this point required the salt in this state to be placed in a desiccator over sulphuric acid. It remained there for several days when the work was resumed. All moisture seemed to be removed and great volumes of hydrobromic acid were given off when the desiccator was opened. The substance had taken on a brownish-red color around the edges

but the central portion was perfectly white. To remove the excess of acid the substance was washed quickly three times with small amounts of water. All of these salts are exceedingly soluble in water and the utmost care is necessary to avoid the entire resolution of the substance. The wash-water was deeply colored by the bromine removed and the salt remained pinkish. It was dried on filter paper and an analysis gave:—

ZrO_2 24.54

This shows that the method of removing the bromine and hydrobromic acid and drying the crystals did not materially alter their composition. Alcohol did not give satisfactory results.

The ether-washed crystals after being allowed to stand in a glass stoppered weighing bottle in the balance case for several weeks showed evidence of absorbed moisture. They were dried again by pressure between folds of bibulous paper, but they could not in this way be brought back to the same state as before, as shown by the analysis:—

| | Found | Previously Found | Calc. for $\text{ZrOBr}_2 \cdot 14\text{H}_2\text{O}$ |
|----------------|-------|------------------|---|
| ZrO_2 | 23.49 | 24.50(av.) | 23.70 |
| Br | 30.58 | | 30.82 |

About 4 grams of these crystals were dried in a glass stoppered flask under a rapid stream of dry hydrobromic acid at a temperature varying between 100° and 120° . The average temperature was about 110° and the drying lasted continuously through three and a half days. After cooling, perfectly dry air was drawn through the flask for a little over ten minutes. This was evidently not long enough as all the free hydrobromic acid had not been removed as shown by the analysis. The substance dried down to a hard white crystalline state which was quite soluble in water. The composition of this residue was as follows:—

| | | |
|----------------|-------|-------|
| ZrO_2 | 34.91 | 34.82 |
| Br | 50.05 | |

If an allowance of 4.5 per cent. be made for the extra

hydrobromic acid not removed, for thirty minutes should have been allowed for the removal of all the acid as was found in the work on the oxychlorides we have:—

| | Found | Calc. for $\text{ZrOBr}_2 \cdot 4\text{H}_2\text{O}$. |
|----------------|-------|--|
| ZrO_2 | 36.31 | 36.21 |
| Br | 47.80 | 47.30 |

Of course such a calculation is not allowable and is given merely to show the possible composition of the dried mass. The experiment was not repeated on account of expense as to both time and materials.

One hundred cubic centimetres of 48 per cent. hydrobromic acid solution were saturated with $\text{Zr}(\text{OH})_4$ by continuous boiling. The volume reached at least 500 cubic centimetres before the hydroxide ceased to be taken up. The solution was never perfectly clear until it was twice filtered through compact filter paper doubly folded. The clear yellow solution was concentrated by evaporation on the water bath. The more concentrated it became the redder it was, finally the color was so deep that it appeared almost black. This was due to decomposition of the hydrobromic acid by organic dust in the air no doubt.

After concentration the liquid was cooled and white crystals separated out. On allowing it to stand 24 hours, or always when made too concentrated by further evaporation, a red jelly separated on top the crystals. In trying to wash this red jelly from around the crystals, for it was very soluble in water, the crystals were also dissolved. The whole was therefore redissolved and after several attempts a set of prismatic needles 1—2 millimetres in length separated out free from the jelly. This jelly was not silicic acid as feared. The mother liquor was poured off, the crystals quickly washed three times with small amounts of water, dried between filter paper and analyzed:—

| | Found | Calc. for $\text{ZrBr}(\text{OH})_3 \cdot 2\text{H}_2\text{O}$ |
|----------------|-------|--|
| ZrO_2 | 34.90 | 34.34 |
| Br | 30.79 | 31.01 |

The solution was further evaporated and another crop

of needle crystals, similar to, but much smaller than, the above obtained. They were washed four times with cold water, dried to a powder between filter paper and analyzed:—

| | Found | | Calc. for $\text{ZrBr}(\text{OH})_3 \cdot \text{H}_2\text{O}$. |
|----------------|-------|-------|---|
| ZrO_2 | 36.86 | 36.35 | 37.91 |
| Br | 32.49 | | 33.33 |

An investigation of the gelatinous oxybromide of zirconium showed that it was a hydrogele. On dialysis the small amount of crystalline oxybromide present passed through the membrane. At the same time the gelatinous compound, if it may be so termed, slowly decomposed into zirconium hydroxide and hydrobromic acid, the latter gradually passing through the septum while the former remained behind.

ZIRCONIUM IODIDE.

Zirconium tetraiodide has been prepared by Dennis and Spencer (*Jour. Amer. Chem. Soc.* XVIII. 673) by passing hydrogen iodide over heated zirconium. It is singularly different from the corresponding chlorine and bromine compounds. It forms a white crystalline sublimate insoluble in water and acids, not hygroscopic and showing no tendency to form oxyiodides with water.

According to Melliss zirconium oxyiodide is not formed by dissolving $\text{Zr}(\text{OH})_3$ in HI . Hinzberg (*Annalen* 239. 253) secured an oxyiodide by precipitating a solution of $\text{Zr}(\text{SO}_4)_2$ with BaI_2 in equivalent amounts. The solution was evaporated over H_2SO_4 and the crystals washed with carbon bisulphide and the analysis gave $\text{ZrI}(\text{OH})_2 \cdot 3\text{H}_2\text{O}$.

In our experiments we found that zirconium hydroxide when precipitated cold was soluble to a small extent in strong aqueous hydriodic acid or could be dissolved by passing hydrogen iodide into water in which the zirconium hydroxide was suspended. Evaporation of this solution over sulphuric acid or calcium chloride gave

needle like crystals strongly colored with iodine and very hygroscopic. Every attempt failed at getting these freed from excess of iodine and properly dried. Washing with ether or with carbon bisulphide was ineffective. A hydrogele was gotten by acting upon zirconium hydroxide with hydrogen iodide which formed on drying a hard horn-like, slightly colored mass, insoluble in water and acids. This contained

Zr 32.14 I. 27.88 H₂O(by difference)28.64

It lost only 11.07 per cent. of its weight after three hours heating at 100—120°.

THE GLABROUS-LEAVED SPECIES OF ASARUM OF THE SOUTHERN UNITED STATES.*

W. W. ASHE.

The following notes on the glabrous-leaved group of the genus *Asarum* are based on a field study of the genus

*While this paper was intended for this JOURNAL its earlier publication as a separate with no credit to this JOURNAL has rendered a few changes necessary in regard to the glabrous-leaved group, while the references to the *Canadense* group have been entirely omitted since Mr. E. P. Bicknell is at present working on this group.

Since this article was put in type I have received a letter from Mr. E. G. Baker, of the Kew Gardens, in reply to one I wrote him, which may throw some additional light on the identity of the Linnaean *Asarum Virginicum*. A comparison of my plants with the Gronovian specimen in the British Museum, on which the Linnaean species is based, was made for me by Mr. Baker. It showed that the Gronovian specimen was more like *A. minus*, but was a smaller plant than that and with a smaller flower. There is an *Asarum* found in the coastal region of North Carolina belonging to this group, and having smaller leaves than any of the Appalachian species, but I have not yet been able to secure flowers from it. It is possible that it may approach in the size and shape of the calyx more closely to the Gronovian specimen than does *A. minus*; but this is mere speculation, so that for the present it is probably better to regard *A. minus* Ashe as *A. Virginicum* L.

extending over several years, so that I have been able to examine growing all the species described except *A. heterophyllum ochranthum*, and *A. callifolium*.

Herbarium material, unless carefully prepared and not too heavily pressed, is unsatisfactory, and gives only a slight idea of the natural shape of the calyx, in which lies the chief difference between these species. For the coriaceous-leaved species the shape of the prolongation of the style beyond the stigma offers good group-characters for determining herbarium material. I have found scarcely any difference in the seeds; and have been unable to secure capsules for satisfactory examination, so I cannot say what characters they offer. Neither the roots nor bracts offer any specific character. The leaves of all the species of this group are at times spotted with white; more frequently this is the case when the plant grows in the shade.

The coriaceous-leaved species are southern Appalachian, with the centre of their distribution in the mountains of North Carolina. One species only, *A. arifolium*, extends into the coastal plain region of the Atlantic States. All the species except *A. arifolium* are rather local.

The nomenclature of the Virginicum group presents some difficulty as to which species represents the original *Asarum Virginicum* of Linnaeus. Plukenet's figure (Alm. 55. t. 78. f. 2.) to which Linnaeus refers might represent any species of this group: it poorly figures *A. macranthum*; somewhat better *A. minus*; and might have been intended to represent either *A. Memmingeri* or *A. heterophyllum*. The Gronovian description does not add any information. I have thought it preferable to follow the practice of several European botanists and ignore, in such a case of uncertainty, the Linnaean name, as it represents a group of at least four species rather than a single plant.

I have to thank many friends for material furnished

me at different times or for permission to examine their material or material placed under their care.

SYNOPTICAL ARRANGEMENT OF GLABROUS-LEAVED SPECIES.

Annual leaf solitary, glabrous, thick, the single flower from the axil of the ovate or reniform subtending bract; calyx glabrous without; the very short epigeal erect or ascending rootstock several times dichotomously forked; roots clustered, thick, numerous, fleshy; anthers oblong-linear, sessile or nearly so, the filaments not prolonged; the 6 thick divergent styles usually 2-forked or notched, bearing the extrose raised stigma below the summit.

(a.) Leaves round-cordate at base; the styles not cleft to the top of the stigma; anthers pointless. (These species except the last constitute the *Asarum Virginicum* of Linnæus.

(b.) The stout prolongation of style barely notched, much wider than the small orbicular stigma.

(c.) Calyx cylindro-campanulate, somewhat contracted at the throat.

2. *ASARUM MACRANTHUM* (Shuttlw.) Small, Mem. Torr. Cl., 5:136.

Homotropia Macranthum Shuttlw.; Small Mem. Torr. Cl., 4:150, as synonym.

Asarum Virginicum var. *grandiflorum*, Mx. in D. C. Prodr. 15:426.

2. *ASARUM MINUS* W. W. Ashe, Contrib. from Herb. No. 1, (1897).

Leaves as in the above but rarely orbicular; tube of calyx cylindro-campanulate, about 1cm wide, about the same length, the very short lobes spreading; peduncle as long as the flower, the large bract pointed; projection of the style very short; the seed oblong.

North and South Carolina and Tennessee. Local. In North Carolina it occurs as low as 150m above sea level. Type locality: Chapel Hill, N. C.

c) Calyx campanulate or oblong-campanulate, not contracted at the throat.

3. *ASARUM HETEROPHYLLUM*, W. W. Ashe, Contrib. from Herb. No. 1. (1897).

Leaf-blades orbicular, ovate or triangular in outline, cordate at base (or occasionally almost hastate), about

the same size as in the above; calyx campanulate, rounded at base, the tube .7-1cm long, the lobes nearly equaling it in length, .8-1cm wide at base; orange-purple, or purple-brown without, brighter within; the very stout barely notched style much prolonged beyond the minute round stigma; capsule short, cylindrous, barely as long as the stamens, scarcely distending the calyx; seed oval.

Mountains of North Carolina, Tennessee and Virginia. Frequent. At once separated from the preceding species by the campanulate calyx, and from *A. Memmingeri* by its open throat and longer calyx lobes.

ASARUM HETEROPHYLLUM OCHRANTHUM, W. W. Ashe, Contrib. from Herb. No. 1. (1897).

Calyx yellow or orange, oblong-campanulate, the spreading lobes as long as the 1cm long tube. No. 18,263 U. S. Nat. Herb.; East Tennessee: E. E. Parry.

b) Calyx urceolate or somewhat contracted at the mouth, the oval stigma thicker than the slender deeply 2-parted projection of the style, and placed near the base of the style.

4. ASARUM MEMMINGERI, W. W. Ashe, Contrib. from Herb. No. 1. (1897).

Leaf-blades about the size of those of *A. macranthum*, nearly orbicular and retuse, or less commonly ovate, their margin entire; petiole often scarcely longer than the leaf-blade; calyx 1.2-1.5cm long, urceolate or urceolate-campanulate, the mouth 7mm or less wide, the short lobes barely 3mm long; the large oval stigma near the base of the style, the very slender, deeply bifid or rarely entire projection as long the stigma; capsule short-cylindrical, when mature greatly distending the calyx; seed sharply triangular.

West Virginia to North and South Carolina. Frequent above 700m altitude. Type locality: Mitchell county, N. C. Named for Mr. E. R. Memminger.

5. ASARUM CALLIFOLIUM Small, Bul. Tor. Cl. 24:7.

Leaf-blades ovate, crenulate on the margins; petiole 2-3

times as long as the leaf-blade, slightly pubescent; bracts reniform; peduncles not longer than the calyx; calyx urceolate, 1.5-2.5cm long, dark green without, purple within, the segments broadly ovate; the large oval stigma at the base of the style, the slender projection deeply 2-cleft.

West Florida. A species recently described by Dr. Small from Dr. Chapman's collection.

(a) Leaf-blades, or some of them, halbert-shaped at base; the projection of the style cleft to the top of the large ovate stigma; anthers short-pointed.

6. *ASARUM ARIFOLIUM* Michx. Fl. Bor. Am. 1:279.

Asarum Virginicum Walt., Fl. 143.

Leaf-blade 6-10cm long, 5-12cm wide, ovate or triangular in outline, halbert-shaped, or rarely round-cordate at base, rounded or pointed at the apex; petiole short or long; calyx from 1.5-2.3cm long, urceolate, rounded at base, much contracted at the throat, the triangular lobes spreading, firm in texture, greenish-purple without, purple-brown within; stigma large, ovate, at the base of the style, the prolongation cleft to the top of the stigma.

Virginia to southern Georgia and Alabama. Common throughout its distribution. Extends in the Carolinas from the sea level to an altitude of about 600m. Probably does not occur in the mountains of Virginia, all specimens which I have seen from there being referable to the next. A very variable species both in habit and form.

7. *ASARUM RUTHII*, W. W. Ashe, Contrib. from Herb. No. 1. 1897.

Leaf-blades halbert-shaped, usually broader than long, commonly larger than in the preceding, deep green; calyx cylindro-ovate, rounded and larger at the base, gradually narrowed toward the mouth, 2.5-3cm long, 1-1.2cm wide, the rounded lobes barely 5mm wide at base, not spreading, purplish-green without, duller within; stigmas and styles similar to those of the preceding.

Southwestern Virginia to Alabama in the mountains, but not occurring above 800m. Named for Prof. Albert Ruth, who sent the species to me. At once separated from *A. arifolium* by its cylindrous calyx, its tube not being contracted at the throat as is that of *A. arifolium*. Type locality: Morristown, Tenn.

Elisha Mitchell Scientific Society.

FOURTEENTH YEAR—PART SECOND.

1897.

A REVISION OF THE ATOMIC WEIGHT OF ZIRCONIUM.¹

BY F. P. VENABLE.

PREVIOUS DETERMINATIONS OF THE ATOMIC WEIGHT.

It is perhaps best to give here a brief outline of previous determinations of the atomic weight of zirconium. Six such series have come under my notice. In three of these the sulphate was used, and in the others the chloride and the double fluoride of zirconium and potassium were used, and in one the selenate.

The determinations of Hermann,² by means of the chloride, can be dismissed as untrustworthy, because of his failure to overcome the difficulties inherent in the use of the chloride as shown by Bailey's work and my own.

The work of Marignac upon the double fluoride I am not in a position to criticise properly, except in so far as to say that his analyses are not very numerous, and that they show a range of nearly three units in the atomic weight.

In 1825 Berzelius ignited the sulphate and gave six determinations of the ratio of the sulphate to the oxide. In

¹ Read at the Washington Meeting American Chem. Society.

² *J. Prakt. Chem.*, 31, 77

some of the experiments he also precipitated the zirconium hydroxide by means of ammonium hydroxide and determined the sulphuric acid in the filtrate by precipitation with barium chloride.

Mats Weibull also used the sulphate and reports seven experiments with an entire consumption of 8.2335 grams. Bailey's own determinations number eight, using in all more than sixteen grams. He gives full data as to his work, and it is well done and merits very careful attention. The following table is copied from his article.* The figures have been recalculated to the basis of O=16.

| | Mean | Maximum | Minimum | |
|--|-------|---------|---------|--------------|
| Zr : Cl | 88.77 | .... | .... | Hermann |
| ZrO ₂ : HCl | 90.14 | 90.98 | 89.29 | Hermann |
| K ₂ ZrF ₆ : K ₂ SO ₄ | 90.53 | 92.80 | 90.06 | Marignac |
| ZrO ₂ : K ₂ SO ₄ | 90.64 | 91.26 | 90.24 | Marignac |
| K ₂ ZrF ₆ : ZrO ₂ | 90.8 | 91.3 | 89.9 | Marignac |
| Zr(SO ₄) ₂ : ZrO | 89.45 | 92.65 | 89.27 | Berzelius |
| Zr(SO ₄) ₂ : ZrO ₂ | 89.48 | 90.38 | 89.13 | Mats Weibull |
| Zr(SO ₄) ₂ : ZrO ₂ | 90.65 | 90.78 | 90.46 | Bailey |

It is manifest that the determinations based upon the ignition of the sulphate are the only ones worthy of further attention. A brief criticism of these is necessary. First, as to Mats Weibull, Bailey says that the temperature used by him in freeing the sulphate from the excess of sulphuric acid was some 50° too low. This would of course give him variable and low results. Berzelius does not give exact data as to temperature used, but he seems to have heated the sulphate too high in driving off the excess of acid. Possibly more stress is to be laid upon the question of the purity of his sulphate and the correctness of the assumption that he had in hand the normal sulphate.

Bailey concludes from his experiments that the sulphate is stable up to 400° C., and that the excess of sulphuric acid can be completely driven off by the use of a temper-

**Chem. News*, 60, 17.

ature between this and 350° C. He further states that a mixture of the salt and free acid, as prepared by him, when heated to this temperature until constant, yields the normal sulphate. It must be said that he gives no proofs of this beyond the amount of zirconia found in his atomic weight determinations.

Whilst certain criticisms of the work of Bailey have occurred to me, I will refrain from mentioning them until I have had opportunity to repeat his experiments and so make myself more familiar with the details of his method.

One criticism I can venture upon now, however. I doubt whether it is possible to ignite, without loss, zirconia along with ammonium carbonate, as was done by Berzelius and by Bailey to remove the "last two or three milligrams of sulphuric acid." I have not ventured to use this method in getting rid of the chlorine which is held just as tenaciously as the sulphuric acid, as I feel sure that it could not be done without loss. Bailey adopted extraordinary precautions to prevent this loss, but it seems to me that it is not the currents of the external atmosphere, as he maintains, which are to be most avoided, but the mass of escaping vapor of the ammonium salts. It is easily possible for him to have lost several milligrams of the finely-divided zirconia in this way, and as he states, each milligram was equivalent to a variation of 0.25 in the atomic weight.

THE WEIGHINGS.

In the following experiments the amounts of substance used varied from one to five grams. To avoid the disadvantage of a small error causing a large variation in the result, I would gladly have used larger amounts of the chloride, but many difficulties met me there. The purification of the zirconium oxychloride is slow and costly. It is best carried out in small portions of a few grams at a time. Some fifty grams have constituted the stock at my

command. The drying of large portions and the subsequent ignition would be exceedingly tedious and time consuming, besides requiring such apparatus as could not be well afforded. Five or six grams have been about the largest amounts that could be well handled at one time. Even such an amount as that required from sixteen to twenty days for the completion of the experiment. It could not safely be hurried through in shorter time.

The weighings were carried out upon an excellently constructed Sartorius balance, intended for a load of 200 grams. The heaviest apparatus used weighed less than sixty grams. The weights were corrected by one which had been compared with the standard at Washington. All objects were weighed against a tare of as nearly the same size, form, and weight as possible, all of the flasks, crucibles, etc., being made in pairs. This partly avoided the necessity for a reduction of the weighings to a vacuum and corrections for moisture, pressure, etc. Such corrections would have had little meaning in comparison with the other inaccuracies of the process and manipulation, and could only serve to give a false appearance of excessive accuracy. The objects were left one-half hour in the balance-case before weighing, experiments having shown that this time was sufficient. Of course the adjustment of the balance was carefully watched, and the balance, which has been used very little, was put to no other use during the progress of these experiments.

METHOD OF WORK.

The purified oxychloride was introduced into a small glass flask having a capacity of 100 cc. This was provided with a glass stopper ground to fit, and also a second one with two tubes arranged for the passage of the hydrochloric acid gas. The arrangement of the tubes was similar to that in an ordinary ether wash-bottle, though both tubes outside were bent downwards and had little

bulbs blown in them for catching moisture, etc. A Thörner bath was found to be very convenient for keeping these flasks at 100°C . The hydrochloric acid was prepared by allowing sulphuric acid to drop into a large flask containing the hydrochloric acid. The gas thus obtained in a regular stream, was passed through a wash-bottle containing sulphuric acid and then through towers filled with glass beads kept moist with concentrated sulphuric acid.

The drying took from fifty to one hundred hours (in some extreme cases.) If the stream of gas was rapid the temperature could rise to 110° or even higher without decomposition of the chloride. A much lower temperature caused this decomposition if the stream was insufficient to keep the flask full of gas. A number of experiments were carried out showing these facts. Indeed, two in the series of determinations were lost by the stream of gas becoming too slow or altogether ceasing for a short while. (Experiments VI and VIII.) It was thought from experiments at first that where this decomposition had begun it was impossible to secure a constant weight of the residue, but this is certainly not true where the decomposition has been only slight. Of course this introduces a chance for error in the method. The drying must be watched quite closely, and not more than eight or ten hours of drying could be easily managed in a day.

At first it was feared to remove the atmosphere preparatory to weighing, and efforts were made at weighing the flasks full of hydrogen chloride. These results were too low and varied among themselves, so that it was evidently impracticable to carry out the experiments in this way. It was found that the hydrochloric acid could be replaced by dry air. The flask was removed from the bath and dry, pure air passed through it for half an hour. It is of course essential that the air be carefully dried. The tubes were then removed and the glass stopper quickly

fitted in its place. It was then ready for placing in the balance-case. The chloride is deliquescent and some trouble in weighing was experienced. If the stopper was well ground there was no appreciable change in the weight in from twenty to forty minutes after placing upon the balance. The loss of weight in the latter part of the drying was very slow. The weighings were taken at intervals of from six to eight hours' heating. The number of weighings necessary before constancy was secured served as a safeguard against error. A series of such weighings is given further on.

After drying, the chloride was dissolved in a small amount of water (redistilled) and this solution, with rinsings, transferred to a platinum crucible. It was evaporated to dryness upon a water-bath, with due precautions against dust, etc., was next heated gradually upon a sand-bath until most of the chlorine had been driven off, and was then slowly raised to the highest temperature attainable by the Bunsen burner. During this latter part of the operation the cover was kept on. Three or four days were thus consumed, the gradual heating giving a coherent flinty mass of glistening semi-translucency which could be safely heated by the water-blast without loss. During the driving off of the chlorine the platinum crucible was more or less attacked, but as this was before the lid was on, there was little chance of loss from this source. This corroded platinum was probably the reddish-brown decomposition product mentioned by Bailey as coming from the ignition of the oxychloride.

The last of the chlorine was driven off by heating with a water-blast for from forty-five to seventy hours. The last weighings were made at intervals of from six to twenty hours and were recorded as constant if they agreed within 0.00005 of a gram. A series of weighings is here given as an example. Experiment No. II. or the first

one successfully carried out in the series, is taken for the purpose.

| | |
|---|---------|
| Weights of zirconium oxychloride: March 28..... | 5.25910 |
| 29..... | 5.25786 |
| 30..... | 5.25760 |
| April 1..... | 5.25762 |

| | |
|---|---------|
| Weights of zirconium oxide: April 11..... | 2.78759 |
| 12..... | 2.78724 |
| 13..... | 2.78583 |
| 15..... | 2.78517 |
| 16..... | 2.78452 |
| 17..... | 2.78451 |

This zirconia was examined for chlorine in most of the analyses and was found to be free from it. In the last three experiments reported in the series, the ignited residue was treated with hydrofluoric acid. Ignition after this treatment was very difficult, as the mass was not compact and coherent. The finely divided zirconia was lost in spite of the most careful treatment. The first was lost altogether and the weighing was not carried out. The second showed, upon the lid signs of the powdered zirconia having been swept out. The total loss of weight, however, was less than one milligram. This could readily be attributed to the zirconia and pointed to the absence of silica unless in insignificant traces.

I think great purity may be claimed for the preparations used in the analyses. Crystallizing from hot hydrochloric acid is apt to remove most known impurities, and they were eliminated beyond the possibility of detection by the ordinary tests. The analyses were not made from the same preparation, but from small quantities prepared at different times and some crystallized ten or a dozen times more than others, yet no appreciable difference could be detected in the results. That these results are not in close accord with one another, is due in part to the deliquescence of the chloride and to the risks involved in the prolonged heating of the oxide.

SOURCES OF ERROR.

Five main sources of error have occurred to me apart from any question as to the purity of the material.

1. The deliquescence of the chloride.
2. The loss of the finely divided zirconia.
3. The corrosion of the platinum crucibles.
4. The attack of the glass flasks by the gaseous and aqueous hydrochloric acid. It is very evident that the glass vessels would suffer when subjected to the action of hydrochloric acid during such prolonged periods. The weighings easily revealed the extent of this action. It was found to vary with different flasks. For instance, flask I lost 0.00116, 0.00031, 0.00023, and 0.00078 gram. On the other hand, flask IV weighed after the first experiment only 0.00011 gram less, and after the next two experiments the loss was 0.00013, and the total loss during three experiments was 0.00024. This is probably transferred mainly as alkaline chlorides to the crucibles and is there volatilized. Sodium could readily be detected upon the lid of the crucible after partial ignition. Of course if all is volatilized then no error is introduced into the experiment, but there may be some non-volatile material also transferred from the flasks. The total amount is so small that the error cannot be a large one.

5. Substances carried into the drying flasks by the stream of gas. Much care was taken to avoid error from this source. The main danger lay in the necessity for the use of some rubber connections. Vulcanized rubber was used. It was freed from excess of sulphur and was replaced by a fresh piece when attacked by the gas. The dry gas does not attack rubber very rapidly. Gaseous sulphur compounds, coming from the sulphuric acid, used in preparing and drying the hydrogen chloride, were probably carried through the drying flasks, but there seems to be no probability of their causing a decomposition of the oxychloride.

THE DETERMINATIONS.

All analyses which were completed under the proper conditions of the method, as already given, are here reported. Experiment III became contaminated from the iron support during the prolonged heating and came out consequently a little high, giving the ratio of $\text{ZrO}_2 : \text{ZrOCl}_2 \cdot 3\text{H}_2\text{O}$ as 53.12. In most of the subsequent analyses the ignition was carried out with the crucible suspended in a platinum wire cage from a glass support. Experiments VI and VIII were dried with an insufficient stream of gas, as already stated, and hence were partially decomposed. They gave 53.57 and 53.8, respectively. The remaining analyses follow:

| | $\text{ZrOCl}_2 \cdot 3\text{H}_2\text{O}$. | ZrO_2 . | Ratio. |
|-----------|--|------------------|--------|
| II..... | 5.25762 | 2.78459 | 52.961 |
| IV..... | 3.53994 | 1.87550 | 52.981 |
| V..... | 3.25036 | 1.72435 | 53.051 |
| VII..... | 1.52245 | 0.80708 | 53.012 |
| IX..... | 2.98802 | 1.58274 | 52.969 |
| X..... | 2.11371 | 1.11820 | 52.949 |
| XI..... | 2.38139 | 1.26161 | 52.978 |
| XII..... | 1.90285 | 1.00958 | 53.055 |
| XIII..... | 8.61847 | 1.38658 | 52.024 |
| XIV..... | 1.07347 | 0.56840 | 52.951 |
| | 26.64828 | 14.11953 | 52.986 |

Calculating these for the ratio $\text{ZrOCl}_2 \cdot 3\text{H}_2\text{O} : \text{ZrO}_2$, taking $\text{H}=1.008$, $\text{O}=16$, and $\text{Cl}=35.45$, we have the following:

| | | | |
|--------------------------|--------|-----------------------|-------|
| Maximum ratio..... | 53.055 | Atomic weight..... | 91.12 |
| Mean " | 52.986 | " " | 90.78 |
| Minimum " | 52.951 | " " | 90.61 |

The atomic weight as determined by Bailey is 90.65. The mean value given in Clarke's Recalculation is 90.40. I purpose repeating the determinations with the oxychloride, with such modifications as have occurred to me since the completion of the above work.

NOTES ON DARBYA AND BUCKLEYA.

W. W. ASHE.

The limited and localized distribution of *Darbya* and *Buckleya*, two genera of southern Appalachian plants (*Darbya* a monotypic genus and *Buckleya* with one Japanese species and the east American plant which is under consideration) has frequently since their discovery been a subject of comment among American botanists. Among the chief factors which have limited their distribution, as Professor Sargent¹ has pointed out in the case of *Buckleya*, are the fact that the sexes are confined to different plants, and the rapid degeneration of the oily albumen surrounding the embryo: the first being an obstacle to the formation of seed; and the latter injuring or destroying the germinating powers of the seed unless they early reach a suitable place for sprouting. Both thus check the increase of new plants.

Another fact which has apparently been overlooked in connection with these plants and which is probably also in a large measure accountable for their localized distribution, is that no efficient means is provided for seed-dissemination. All animals that I have tried with the seed reject them; in regard to birds I cannot speak. The heavy fleshy seed have evidently been developed to sprout and grow near the parent plants. The seed of *Buckleya*, it is true, since it is found only along and near streams, are apt to be transported by the stream. This is evidently the case with *Buckleya* along the French Broad and Pigeon rivers. Kearney² records it as growing at an elevation of 30m above the river on the side of a wooded

¹ Gard. and Forest 3: 236.

² Bull. Tor. Bot. Cl. 24: 561.

bluff near the original station at Paint Rock. I have noticed it, however, only a few meters at most away from the river or from some stream.

But what I regard as restricting the distribution of the plants fully as much as any of the above assigned causes is the heretofore unrecorded fact of their parasitism. Although Dr. Gray³ dug up *Buckleya* to remove it to Cambridge for the botanical garden at that place; and more recently Professor Sargent⁴ has carried both seed and young plants from Paint Rock to the Arnold Arboretum, where a few of the plants were induced to grow, it was not noticed by either that *Buckleya* formed root-attachments to other plants. Great difficulty was encountered in inducing the plants to grow, and what is not strange, all means of propagation failed. Mr. J. G. Jack writes me that one of the plants of *Buckleya* which Dr. Gray took to Cambridge lived for a great many years beneath a hemlock where it was planted in the Botanic Garden and to the roots of which I think it had undoubtedly formed attachments.

I have been aware of the parasitic nature of these plants for several years. The parasitism of *Darbya* was first discovered, and subsequently that of *Buckleya*. In the autumn of 1894 Mr. F. E. Boynton and I collected specimens of *Darbya* near Salisbury, N. C., where I had previously noticed the plants. He had already suggested the parasitism of *Pyrularia*, as recently published,⁵ and which I was soon after able to verify. We consequently suspected the parasitism of *Darbya*, knowing that many of the *Santalaceae* are root-parasites.⁶

³Gard. and Forest, l. c.

⁴Ibid.

⁵Distribution from Biltmore Herbarium: *Pyrularia oleifera* Mx. parasitic on roots of trees etc.

⁶Hieronymus (Die Natuerlichen Pflanzenfamilien von Engler und Prantl, 203) gives only the following genera as being root-parasites: *Osyris*, *Santalum*, *Commandra*, *Thesium*, *Arjona*, and *Quinchamalium*.

On carefully digging up the plants the roots, or what I rather regard as prolonged subterranean stems, were found to be very much as Miss K. A. Taylor¹ has described them. The plants propagate by these underground stems which are 8-15mm in thickness and similar to those of *Commandra*, but larger. These, in the centre, are firm, tough and woody. This core of wood is covered with a thick, tough, though rather corky bark, 3-4mm in thickness. From the lower side of this are frequent small roots, none of them over 3mm in thickness which form attachments to the roots of the trees and shrubs growing around. These slender roots are attached to the host by disk-shaped haustoria, somewhat similar in structure to those described for *Commandra*.²

Miss Taylor³ gives the length of the "roots" dug up at Columbia, S. C., as being only a few yards. They are frequently very many yards in length, however. One plant I recently had dug up, had an unbroken stem measuring nearly 10cm, and as there was a growing-point at only one end the length must have exceeded this. The vegetative stems are apparently developed in no regular order and from no evident buds, though this will bear farther examination. The stems lie from 12-15cm below the surface and fork at frequent but irregular intervals. The underground stems are tipped with a growing-point in appearance not unlike that of many of the large roots of plants. As this growing-point pushes forward during the season of growth, many small roots are developed from the lower side of the newly formed stem. These penetrate either straight down or somewhat laterally until they reach the roots of some tree or shrub suitable for attachment, where haustoria are formed. The longest of these roots found was about 3cm in length. While

¹Gard. and Forest, 7: 94.

²Von Schrenk, Bul. Tor. Bot. Cl. 12.

³Gard. and Forest, 1. c.

developing and before attachment is secured they are covered with thin-walled cells, but old roots which have been attached to a host-root for some time, appear to have enlarged while the walls of the epidermal cells have become thickened. It is possible that the newly developing root is capable of absorbing from the soil, while the older ones that have already made attachment are no longer able to absorb; but neither of these statements is yet definitely known to be true. And since the seedling plant of *Buckleya* as I have recently found out by planting them, is thus able to exist for some time without the intervention of attachments, it is quite possible that not only the young plants of *Darbya* may do the same, but that newly developing roots as well may possess this ability to derive nutriment from the soil. This, however, is merely conjecture. These roots showed few forks and no roots could be found, except those developed in the spring, which had not formed an attachment or were evidently broken, so it is probable that those roots which do not find attachment soon lose their vitality and die.

Polygamous plants seem to mature fruit only when fertilized by staminate plants or perhaps by other seedling polygamous plants. Near Chapel Hill in the lower valley of Morgan's creek polygamous plants are found for three or four miles along the narrow strips of alluvial soil that border the creek, but no seed are produced. This would seem to indicate that all the groups of plants along Morgan's creek have a common origin and are vegetatively produced from a common stock. The staminate plant is not found near Chapel Hill.

Near Salisbury, N. C., many groups of the sterile plants are to be found within an area of two or three square miles, but as no trace of a polygamous plant has been found within twenty miles of these groups I am inclined to trace these, as well, to a common plant and derived from it vegetatively. This view is further strengthened

by the fact that in the few localities where seed are produced both sexes occur abundantly, though usually the plants are separated into more or less evident groups, as Miss Taylor¹⁰ observed at Columbia, S. C.

If these disassociated groups of plants are of common origin, *Darbya* would seem to be, under its natural conditions, a plant which readily and rapidly propagates. In one place the underground stem seemed to have made as much as three feet of growth in one year.

I have extended the distribution of *Darbya* as far north as Halifax county, southern Virginia. Dr. Mohr has found it as far west as northern Alabama; and in Georgia it has been found as far south as Macon. The most eastern place where it has been found is near Willardville, Durham county, N. C. I have recorded from my own observation thirteen stations for the plant in Virginia and the Carolinas, the numerous groups of plants around Salisbury and Chapel Hill, and similar groups at other places, being regarded as constituting a single station. At only three of these stations are seed known to be produced. The staminate plants are much more abundant than the polygamous.

As in the case of *Commandra* attachments are made to the roots of most trees and shrubs. The following have been verified to serve for *Buckleya*: *Quercus alba*, *Q. minor*, *Q. velutina*, *Q. Marylandica*, *Q. nigra*; *Pinus echinata*, *P. Virginiana*; *Hamamelis*; *Vaccinium corymbosum*, *V. vacillans*; *Hicoria Carolinae-Septentrionalis*, *H. alba*; *Crataegus* sp. ign.; *Acer rubrum*. It is probable that this list could be extended by carefully following the roots.

Darbya, I am convinced, can be grown by planting the seed among trees or shrubs that will serve as hosts in a place where it will not be necessary to move it. If it is desired to move the plants the seed should be planted in

¹⁰Gard. and Forest, 7: 94.

jars with seedling oaks or pines, and when large enough to set out remove the contents of the jar without disturbing the roots of the plants.

Buckleya, since it sometimes reaches the size of a small tree, is the largest known American parasite. It has many more fibrous roots than *Darbya* and the subterranean stem is not so extensive. The clasping disks by which attachments are made are larger and somewhat more cup-shaped than are those of *Darbya*. It is chiefly parasitic on the small roots of hemlock, beech, sugar maple, birch (sp. ind.) and red oak. It can be cultivated in the same manner as *Darbya*.

The manner of propagation of *Pyralaria* is like that of *Darbya* but the underground stems are shorter and more abundantly supplied with small roots.

ROBINIA BOYNTONII SP. NOV.

¹CONTRIBUTION FROM MY HERBARIUM. NO. II.

W. WILLARD ASHE.

For many years a plant which was originally described by Pursh² as *Robinia hispida* var. *rosea* has been confused with the *Robinia hispida* of Linnæus by both American and European authors. This confusion originated from the inadequacy of Pursh's³ description; and has been continued by later writers who, having no specimens of Pursh's plant for comparison, transferred its name to smooth or nearly smooth forms of *R. hispida* which seemed in part to agree with the description of the variety *rosea*. As a matter of fact the variability of

¹ Received March 18th, 1898.

² Flora Amer. Sept. 2: 488.

³ *Robinia rosea* B. R. foliolis plerumque alternis, ramulis glabriusque.

hispida in those characters which were usually relied upon for segregation has justified it.

Pursh, in spite of his brief and unsatisfactory technical description, in making some general references to the distribution, etc. of the plants he had just described, compares the relative sizes of *R. hispida* and *R. hispida* var. *rosea* in such a manner as to leave no doubt in regard to their identity: "The variety *B* is less hispid and grows to a considerable large upright shrub, whereas the original *hispida* is a low stragling plant." This accurately presents the salient features of the habit of the two plants, and enables one, familiar with both in the field, to easily differentiate the true *rosea*.

But while usually a form of *hispida* is referred to *rosea*, in the last edition of Gray's Manual of Botany⁴ the description of *hispida* includes not only all the true forms of *hispida*, but the *rosea* of Pursh as well, the latitude of the description embracing plants with "less bristly or naked branches, smaller flowers etc." than the immediately preceding technical description covered. The allusion to small-flowered forms can only be interpreted as a reference to *rosea*, as a comparison of the description of the two plants which follows will show.

It is probable that Marshall as well included both plants in his *rosea*, which is usually referred only to *hispida*, as he mentions the large size that some specimens of his plant attain, whereas the true *hispida* is always of small size.

American botanists, when separating the two plants at all, have retained the *rosea* under its original name, and where first placed as a variety of *hispida* but the two plants are so different that *rosea* is eminently worthy of specific rank.

As no additional names have been proposed by European botanists there is no tortuous synonymy to be traced.

⁴Sixth edition, 134.

Robinia dubia Fouc.⁵ and the other names included in its synonymy refer to a plant which has long been cultivated in Europe, and which, if not a hybrid⁶ between *R. Pseud-acacia* and *R. viscosa*, is a garden variety of *R. viscosa*. It is separated from the plant under consideration no less by its stout spines, than by the presence on its twigs and pods of the viscid secretion so characteristic of *viscosa*.

Since Pursh's name *roscæ* is excluded by the previous use of it by Marshall and du Monceau for *R. hispida*, and no other has been published, I propose the name *Boyn-tonii*, complimentary to Mr. F. E. Boynton of Biltmore, N. C., an observer having a most extensive acquaintance with the southern Appalachian flora.

The proposed species is characterized as follows:

Robinia Boyntonii, sp. nov.

Robinia hispida var *roscæ* Pursh, Fl. Amer. Sept. 2:488.

Robinia roscæ D. C. Pròd. 2:262.

Robinia hispida (in part) Gray, Man. Fifth ed. 131.

Mature twigs 3-4mm thick, terete, a bright varnished brown, glabrous; stipules minute, awl-shaped, caducous; shoot of the season at first minutely pubescent, at length glabrous or nearly so. Leaves 10-16cm long, leaflets 9-13, mostly placed alternately, short-stalked, oblong or oblong-ovate, 2-4cm long, 1-2cm wide, tipped with a slender mucro. Petiole and leaflets minutely pubescent when young, soon glabrous. Racemes axillary, erect or nodding, 7-9cm long, one-half to two-thirds the length of the leaves, rather loosely 8-12 flowered. Flowers on slender, erect or spreading pedicels 4-5mm long, rose-purple, pink, or purple and pink on the outer portion, white or much paler towards their base, when expanded

⁵ In Desv. Journ. Bot. 4: 204.

⁶ London (Trees and Shrubs Brit. 236) stated that it is a hybrid which originated in 1730.

barely 2cm long; blade of wing abruptly contracted into the slender claw; keel rather broad, each portion spatulate in outline. Calyx short, 6mm in length, as broad as long, the very short, broad lobes, 2-3mm long, abruptly acute, smooth, or minutely pubescent when young. Pod slender, many seeded, smooth, even when young.

A shrub with virgate branches, 1.5m to 2.5m in height, or exceptionally larger and assuming an arborescent form. Mountains of Virginia ? and western North Carolina to Georgia, usually at high elevations. It is one of the handsomest of the Appalachian species of the genus, equalling in brilliance of color and abundance of flowers *R. viscosa*. Growing specimens of this plant have been extensively distributed by the Kawana Nurseries of Kawana, N. C.

Specimens examined:

Kelsey: Mitchell county, N. C.

J. A. Tatham: Cherokee county, N. C.

Ashe: Randolph county, N. C.

Ashe: Greenville county, S. C.

The plant is local, but fairly abundant where it occurs, and it should be frequent in cultivation. *Robinia hispida* L. with which it has been confused has the following characters:

Robinia hispida L., Mant. 1: 101.

Robinia rosea Duham., Arb. 1. t. 18.

Robinia rosea Marsh., Arb. 134.

Robinia montana Bartr., Trav. 335.

Pseudacacia hispida Moench, Meth. 145.

Aeschynomene hispida Roxb. (?)

Mature twigs rather stout, 4-5mm thick, terete, dark brown, bristly-hispid, papillate, or nearly smooth. Shoot of the season from densely bristly-hispid with stiff purple hairs to nearly smooth; stipules, minute early deciduous. Leaves rather large, 12-20cm long, petiole usually hispid; leaflets 7-11, rarely 13, mostly opposite, short-stalked, ovate or orbicular, 2-3cm wide, 2-4cm long,

tipped with a short, stout micro, cordate or subcordate at base, more or less pubescent when young, soon smooth. Racemes axillary, nodding or drooping, 3-5 flowered, 4-5 cm long, one-fifth to one fourth the length of the leaves, peduncles usually hispid. Flowers purple-blue in the bud, becoming on expansion deep purple or red-purple, but lighter-colored at the base, when open 2.5cm or more long; blade of wing projecting beyond point of union with claw, so as form a narrow but deep sinus between them; each division of keel oblong, abruptly contracted into the claw. Calyx 8-10mm long, the 4-7mm long acuminate lobes much longer than the short broad generally hispid tube. Pod short, stout, few-seeded, glandular-hispid.

A low straggling shrub, 1-3 feet in height. It occurs from Virginia to Georgia and Alabama? in and near the mountains. In the mountains it is for the most part confined to the crests and dryer southern flanks of ridges, and is not uncommon. Its altitudinal distribution is from 300m to 1500m. It seems to pass gradually into the low-country form which is nearly destitute of bristles and more or less pubescent.

Robinia Boyntonii is separated from *R. hispida* L. by its greater size, smooth pod, oblong leaflets, many-flowered racemes, short calyx-lobes and smoothness.

From *R. viscosa* Vent. it is separated by having only about one-half the number of leaflets, a smooth pod and the absence of viscid secretion.

In many characters it is nearly allied to *R. Pseudacacia* L: The leaflets are about the same number, twigs and pods are smooth; but the flowers are rose-colored and smaller than in *R. Pseudacacia* and no stipular spines are developed.

Since the above was put in type I find that *Robinia Boyntonii* has been distributed by the Biltmore Herbarium, but without a name, as No. 3268: Near Highlands, Macon county, N. C.

ON THE ORIGIN OF THE VERTEBRATE SENSE ORGANS.

BY H. V. WILSON.

The belief that the chief sense organs of vertebrates have been evolved from a longitudinal series of simple and superficially situated organs rests on morphological evidence, which if not conclusive is yet very considerable.

Beard¹ in 1885 described in selachian embryos a series of rudimentary sense patches (ectodermal thickenings, one above each gill cleft). These he termed the branchial sense organs. Similar organs have been found by Beard and several observers (Froriep, Kupffer, etc.) in the embryos of other Ichthyopsida, birds, and mammals. It may be confidently asserted that a phylogenetic significance attaches to these formations, and that the ancestors of existing vertebrates had a series of sense organs (two series, one more dorsal than the other: Kupffer) situated in the anterior (branchial) region of the body.

The sense organs of the lateral line, and of the mucus canals of the head, found in adult fishes, tailed amphibia, and in anuran larvae, are known to arise by the proliferation of the above mentioned embryonic organs, which thus became extended far beyond the seat of their original appearance.

The position and mode of origin of the embryonic nasal and auditory invaginations led Beard to regard these organs as homologous with his series of branchial sense organs. And this conclusion has been in general accepted by later investigators.

It might some years ago have seemed impossible to in-

¹ Branchial Sense Organs of Ichthyopsida. Quart. Journ. Micr. Sci. 1885.

clude the eye in this lateral series of homodynamous organs. But while the eyes (optic vesicles) ordinarily originate as diverticula from the fore-brain, it is now known that in many forms they make their appearance as invaginations of the surface ectoderm, long before the neural folds have closed. In this condition the optic vesicle is a circular depression, substantially like the auditory or nasal pit. Later these depressions are carried inwards with the invaginating neural plate, and then appear as outgrowths of the brain. The early appearance of the optic vesicles has long been known in mammals, but until within recent years it has been regarded as a peculiar and precocious feature of this group. Through the observations of Whitman², Eyclesheimer³, and Locy¹, we have learned that the optic vesicles originate in this manner in several amphibia, in selachians, and the chick. These observations at least lend us a basis for the comparison of the eyes with the other segmentally arranged sense organs, and meantime (Locy loc. cit. p. 556) "we are in the attitude of awaiting further facts."

The scattered integumentary sense organs (taste buds, touch corpuscles) have not been shown to be derived from anlagen, serially homologous with the anterior segmentally arranged series.

The derivation of the chief vertebrate sense organs from a longitudinal series of superficial neuro-epithelium patches, might at first thought be construed into a sound argument for the annelid-theory of vertebrate ancestry. But when it is borne in mind that the vertebrate series is, in the embryo, confined to the anterior (branchial) region, *whence the organs spread back over the trunk and forwards over the head by proliferation*, it will be recog-

²Journal of Morphology, 1889, p. 593.

³Journ. Morphology, 1893, Vol. VIII, No. 1, p. 189.

¹Contributions to the Structure and development of the Vertebrate Head. Journ. Morphology, 1895.

nized that this series of organs differs at any rate in the matter of distribution, from the segmentally arranged organs extending along the side of the body of certain annelids (Capitellidae, Eisig⁵; leeches, Whitman⁶.)

The small number and local distribution of the segmental sense organs of the vertebrate embryo, as compared with the condition after the lateral line has become well developed, suggests inevitably the question: If so much of the metameric character of these organs in the adult (or larva) is clearly secondary, how deeply seated is the metameric arrangement of the primitive (few, embryonic) branchial sense organs? Is it possible that this series of organs has arisen from a single pair (one on each side of the body), as some (Brooks⁷) believe the gill clefts to be traceable to a single pair?

There exist certain observations which it is possible to interpret as supporting this idea. In 1891 I described⁸ for a teleost (Serranus embryos) a sensory anlage on the side of the head. The reference to these observations in Minot's Human Embryology (1892) is succinct, and indicates the state of our knowledge on this point at the time: "This thickening [the anlage on each side of the head] forms a long shallow furrow, which subsequently divides into three parts, of which the first becomes a sense organ over the gill cleft, the second, the auditory invagination, and the third, the anlage of the sense-organs of the lateral line. This peculiar development confirms the notion that all these organs belong in one series, but the appearance of a continuous thickening as the anlage of them all, has as yet been observed only in this fish, and may not indicate a corresponding ancestral condition. Unfortun-

⁵ Die Segmental-organe der Capitelliden. Mitt. a. d. Zool. Sta. zu Neapel, 1879.

⁶ Some New Facts about the Hirudinea. Journ. Morphology, 1889.

⁷ The Genus Salpa. Baltimore, 1893.

⁸ Embryology of the Sea Bass. Bull. U. S. Fish Comm. Vol. IX.

nately Wilson was unable to make out anything as to the connection of the sensory plate with the ganglia. The sense organ above the gill cleft, although differentiated, is a larval structure only, and disappears in the adult" (quoted from Locy *lc.* p. 548).

Locy writing on elasmobranch development (1895, *lc.*) goes on to show the advance of our knowledge in this matter—"A quite similar condition is now known to obtain in some elasmobranch forms. Mitrophanow in 1890 published a preliminary report of his observations on the lateral line of *Acanthias* and other elasmobranchs. In 1893 he published a full report of the same, illustrated by many figures. He describes a continuous thickening of the epidermis along the sides of the head, embracing the territory of the roots of the seventh to tenth nerves. From this thickening there is separated the material for the auditory saucer, the branchial sense-organs, and the beginning of the lateral line. My observations on this region in *Squalus* agree with those of Mitrophanow." Locy's observations are briefly described further on in his paper p. 517, the author mentioning that "a consideration of the so-called branchial sense-organs and their ganglia is reserved to be published later."

The discovery that the common anlage was not a peculiar feature of a teleost species, but existed in widely different Ichthyopsida Mitrophanow⁹ describes the anlage not only for selachians, but for teleosts, cyclostomes, and amphibia as well, indicated that the point was one worth following up.

The *Serranus* egg is a small, pelagic egg. In it the common anlage is more sharply differentiated from the general ectoderm, than in the selachian and cyclostome forms studied by Mitrophanow and Locy. In *Serranus* the anlage is a furrow, in the latter forms it is a thicken-

⁹ *Étude embryogénique sur les Sélaciens.* Arch. de Zool. exp. et gen 1893.

ing. In the teleost forms studied by Mitrophanow (species not stated) the anlage develops in same way as in *Serranus*—as a furrow.

The salmon egg is very different from that of *Serranus*. It is large, and with relatively firm yolk. At my suggestion Mr. J. E. Mattocks undertook the problem of ascertaining in the first place, whether the common anlage existed in the salmon embryo, and if so, what was its character. The result of Mr. Mattocks's work (published in *Anat. Anzeiger* XIII Bd. Nr. 24), was to show that the common anlage does exist in the salmon; that it is not a furrow, as in *Serranus*, but a thickened stripe of ectoderm as in selachians; that it divides into three parts, the middle becoming the auditory sac, the posterior the rudiment of the lateral line, and the anterior remaining as a very noticeable thickening situated above the anterior gill clefts. It thus turns out, as might have been expected, that the peculiarly distinct, furrow-like character of the anlage in *Serranus*, is not universal in teleosts. The difference in the character of the anlage between *Serranus* and *Salmo* is perhaps associated with the difference in the character of the two eggs. One is small, light, the embryo consisting of comparatively few cells, the other large, heavy, the embryo relatively massive and of many cells. Without dwelling on this point (which like other similar questions can be cleared up only by an extensive comparative study of closely related forms, aided, where the method is practicable, by intelligently "put" experiments—in this connection see Davenport's very suggestive "Catalogue of the processes concerned in Ontogeny." *Bull. Mus. Comp. Zool.* Vol. XXVII. No. 6), it is safe to say that comparative embryology lends some support to the generalization that in embryos of the former type invagination or evagination is apt to occur, while in embryos of the latter type the invagination or evagination is frequently represented by solid in-

growths or outgrowths i. e. thickenings. — compare for instance the formation of the mesoblast of *Amphioxus* with that of other vertebrates, the invaginate gastrula of *Leucifer* with the corresponding stage of such a form as the lobster.

If we suppose (as a basis for further work, rather than for any other purpose) that the common lateral anlage in the ichthyopsidan embryo indicates the presence in the chordate ancestors of a single elongate sense-organ on each side of the head, then what was the character of this organ? Was it a sac (groove), or merely a superficial sensory area? It is worth while often, to put the question, even if the answer is not forthcoming. Certainly the answer is not now at hand. Though merely putting the question calls to mind the cephalic slits of nemerteans, and Hubrecht's ingenious, if not very popular theory of chordate ancestry.

NOTES ON NORTH CAROLINA MINERALS.*

BY J. H. PRATT.

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INTRODUCTORY NOTE.

The contents of this paper are notes on the North Carolina minerals that have been collected during the past few years. Some of these have already been published

*By permission of the Director of the N. C. Geological Survey.

during the past year, and reference is made to this under the head of these minerals.

These notes are intended primarily for a Bulletin on the Mineral Resources of North Carolina, but the more important of these are published as occasion offers.

WELLSITE, A NEW MINERAL.*

Occurrence.—This mineral occurs at the Buck Creek (Cullakane) corundum mine in Clay Co., North Carolina, and was collected by Professor S. L. Penfield and the author during the summer of 1892 while engaged in work on the North Carolina Geological Survey.

The corundum vein in which the mineral is found is composed chiefly of albite feldspar and hornblende, and penetrates a peridotite rock, dunite, near its contact with the gneiss. The peridotite outcrop is one of the largest in the State and has been thoroughly prospected for corundum. At only one of the veins opened was the new mineral found, although a careful search was made for it at all the openings, especially those affording feldspar. No mining has been done at the locality since 1891, but if work is resumed and the veins uncovered, more of the material will undoubtedly be found.

The mineral is found in isolated crystals mostly attached to the feldspar but also to hornblende and corundum, and is intimately associated with chabazite, (see p. 70), which occurs in small transparent rhombohedrons.

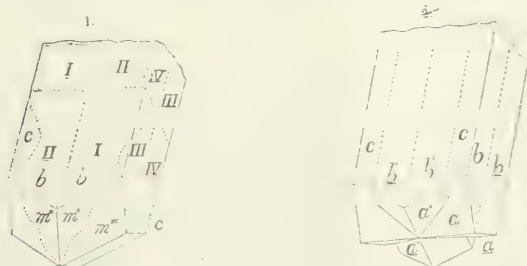
The largest crystals that were observed were not over 1^{mm} in diameter and 2^{mm} in length.

Crystalline form.—The crystals belong to the monoclinic system and they are twinned similarly to those of harmotome and phillipsite. The common habit is shown in fig. 1, which represents a combination of twinning about $c, 001$ and $c, 011$. The crystals are practically square prisms, terminated by pyramidal faces, thus imi-

*Am. J. Sci., Vol. III, p. 443, 1897.

tating closely a simple combination of a prism of one order and a pyramid of the other in the tetragonal system. The apparent prismatic faces are formed for the most part by the pinacoid faces, b , but the crystals interpenetrate each other somewhat irregularly so that portions of the base c , 001, coincide with b , fig. 1. The lines of twinning on the pinacoid faces between b and b twinned are generally regular, while those between b and c and also those which cross the prism faces m , 110 (the apparent pyramid) are generally quite irregular. The b faces do not show the striations parallel to the edges b and m , which, meeting along the twinning lines, often reveal the complex nature of such crystals, nor were any reëntrant angles observed parallel to the edges of the apparent prism as are common on phillipsite and harmotome.

Fig. 2 represents another habit of the crystals where m , 110 is wanting and a , 100 is in combination with b , 010. The method of twinning is similar to that already described, but the crystals being terminated by a , 100 instead of m , 110 show prominent reëntrant angles at their ends. These crystals are very similar to those of harmotome from Bowling near Dumbarton on the Clyde, described by Lacroix.*



The only forms that were observed were a , 100; b , 010; c , 001 and m , 110, with c , 011 only as twinning plane.

The faces of the crystals are somewhat rounded and

*Bull. de la Soc. Min. de France, No. 4, p. 94, 1885.

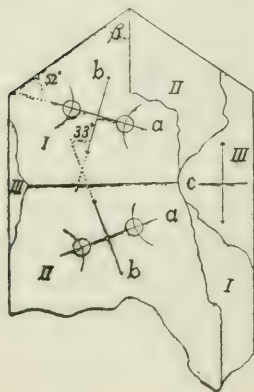
vicinal so that the reflections were not very perfect. The angle of the apparent prism $b\Delta b$ twinned is approximately 90° . Also the angle $m\Delta m$ over the twinning plane 011 could be measured only approximately, varying from $0^\circ 49'$ to $1^\circ 25'$. The approximate angles are given below, and from those marked with an asterisk the following axial ratio was calculated:

$$a:\bar{b}:c = .768 : 1 : 1.245; \beta = 53^\circ 27' = 001\Delta 100$$

| | Measured | Calculated. |
|--------------------------------|--|----------------|
| $b\Delta b$, 010 Δ 010 | * 90° (over twinning plane) | |
| $a\Delta a$, 100 Δ 100 | * $73^\circ 6'$ (over twinning plane) | |
| $b\Delta m$, 010 Δ 110 | * $58^\circ 19'$ | |
| $c\Delta a$, 001 Δ 100 | $53^\circ 27' = \beta$ | |
| $c\Delta m$, 001 Δ 110 | $60^\circ, 59^\circ 45', 59^\circ 57'$ | $59^\circ 33'$ |

Physical properties.—The crystals are brittle and show no apparent cleavage. The luster is vitreous. Many of the crystals are colorless and transparent while others are white. The hardness is between 4 and 4.5. The specific gravity taken on a number of separate crystals, by means of the heavy solution, varied between 2.278 and 2.366. This variation was probably due to the difference in the ratio of the barium to the calcium in the different crystals.

3.



A section parallel to the pinacoid faces b , 010, the apparent prism, revealed in polarized light the structure shown in fig. 3. The parts I and I extinguish simultaneously, as also II and II; while portions III, which are parallel to the basal plane, show parallel extinction. The section showed something of a zonal structure, so that the extinction could only be measured approxi-

mately, Using the Bertrand ocular, this was found to be 33° from one pinacoid on to the other over the twinning plane. The axis a makes an angle of 52° with the vertical axis c' in the obtuse angle β .

The double refraction is positive and weak. The acute bisectrix c is at right angles to the pinacoid 010, and the divergence of the optical axes is large. $2E$ probably varies from 120° to 130° , but this could not be measured directly.

Chemical analysis.—The mineral was purified for analysis by means of the heavy solution and that which was used varied in specific gravity from 2.278 to 2.360.

The analyses were made by Mr. H. W. Foote,** who describes the methods used as follows:

“Water was determined by loss on ignition, and silica and alumina by the ordinary methods after fusion with sodium carbonate. The filtrate from the alumina precipitation was evaporated with aqua regia to remove the large excess of ammonium salts and a small amount of ammonium chloride was again added. Calcium, barium and strontium were then precipitated together, with a considerable excess of ammonia and ammonium carbonate, and magnesia was determined in the filtrate. The mixed carbonates were dissolved in hydrochloric acid evaporated to dryness and taken up in about 300^{cc} of water. The method used for separating barium was that recommended by Fresenius.* To the hot solution, a few drops of acetic acid were added and 10^{cc} of a 10 per cent solution of ammonium chromate containing a small amount of dichromate. After standing until the solution became cold, the clear liquid was decanted and the precipitate of barium chromate was washed with a weak chromate solution and with water. The precipitate was

*Zs. Anal. Chem., xxix, 426.

**Of the Chemical Laboratory of the Sheffield Scientific School, New Haven, Conn.

dissolved in 2^{cc} of pure dilute nitric acid, which was then partly neutralized with ammonia. Ammonium acetate was added and 10^{cc} of chromate solution as before, and after standing, the precipitate was filtered on a Gooch crucible and weighed as BaCrO₄.

"The filtrate from the barium precipitation was concentrated somewhat, and calcium and the small quantity of strontium precipitated as before. They were ignited and weighed as oxide. Strontium was then separated by treatment with amyl alcohol and determined as sulphate.

"The alkalis were determined by a Smith fusion in the ordinary way."

The results of the analyses are as follows:

| | I. | II. | Average. | Ratio. | |
|--|-------|-------|----------|--------|--------------|
| SiO ₂ | 43.62 | 44.11 | 43.86 | .731 | = 3.00 |
| Al ₂ O ₃ | 25.04 | 24.89 | 24.96 | .244 | = 1.00 |
| BaO | 5.00 | 5.15 | 5.07 | .033 | } .228 = .93 |
| SrO | 1.12 | 1.18 | 1.15 | .011 | |
| CaO | 5.76 | 5.84 | 5.80 | .104 | |
| MgO | 0.61 | 0.62 | 0.62 | .015 | |
| K ₂ O | | 3.40 | 3.40 | .036 | |
| Na ₂ O | | 1.80 | 1.80 | .029 | } = 3.04 |
| H ₂ O | 13.32 | 13.39 | 13.35 | .742 | |
| | | | 100.01 | | |

The ratio of SiO₂ : Al₂O₃ : RO : H₂O is very close to 3 : 1 : 1 : 3, which gives the formula R''Al₂Si₃O₁₀ · 3H₂O. The ratio of BaO : CaO : K₂O + Na₂O in the above analyses is nearly 1 : 3 : 2 and the theoretical composition calculated for this ratio is given below together with the analysis after substituting for Na₂O its equivalent of K₂O and for MgO and SrO their equivalents respectively of CaO and BaO and then recalculating to 100 per cent.

| Theory for $R''Al_2Si_3O_{10} \cdot 3H_2O$ where R is $\frac{1}{3}Ba$, $\frac{2}{3}Ca$, $\frac{2}{3}K$. | | |
|---|--------|--------|
| SiO ₂ | 43.12 | 42.87 |
| Al ₂ O ₃ | 24.54 | 24.27 |
| BaO | 6.65 | 6.62 |
| CaO | 6.59 | 7.27 |
| K ₂ O | 5.98 | 6.10 |
| H ₂ O | 13.12 | 12.87 |
| | 100.00 | 100.00 |

Experiments were made to determine at what temperatures the water was driven off, and the results are given in the following table, the mineral being heated in each case until the weight became constant. The last trace of water could only be driven off by heating the mineral over the blast lamp.

| | Loss. |
|-----------------------|----------|
| At 100° C | nothing. |
| 125 | 1.93 |
| 175 | 1.48 |
| 200 | 0.92 |
| 260 | 2.45 |
| 295 | 1.24 |
| Red heat..... | 4.96 |
| Over blast lamp | 0.33 |
| Total..... | 13.31 |

As is seen from the above, about one-third of the water, or one molecule, is given off between 100° and 200°, another third approximately between 200° and 300°, while the remainder is expelled only at an intense heat. This would indicate that the water exists in three different conditions in the molecule. If only that which is expelled below 200° be regarded as water of crystallization, the composition would be $H_1R''Al_2Si_3O_{12} + H_2O$.

That the new mineral would be closely related to the

phillipsite group of the zeolites, was expected from the first on account of its crystalline form, and this relation is very satisfactorily brought out by a comparison of the crystallographic properties and chemical composition.

They all have very nearly the same axial ratios:

| | a | b | c | |
|-----------------------|-------|-----|-----------|----------------------------------|
| Wellsite | 768 | : 1 | : 1.245 | $\beta = 53^\circ 27'$ |
| Phillipsite | 70949 | : 1 | : 1.2563 | $\beta = 55 \quad 37$ |
| Harmotome | 70315 | : 1 | : 1.2310 | $\beta = 55 \quad 10$ |
| Stiblite | 76227 | : 1 | : 1.19401 | $\beta = 50 \quad 49\frac{3}{4}$ |

In their habit and method of twinning, they are also very similar, all the crystals being uniformly penetration twins. This is especially noticeable between the new mineral and phillipsite and harmotome which are common as double twins with $c, 001$ and $c, 011$ as twinning planes.

The place of the mineral in the phillipsite group is clearly shown by a comparison of their chemical compositions. Arranged in order of their proportions of silica and water to the bases, we have the following interesting series, in which R represents the bivalent elements:

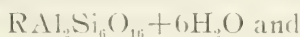
| | |
|-----------------------|---|
| Wellsite | $RA_2Si_3O_{10} \cdot 3H_2O$ |
| Phillipsite | $RA_2Si_4O_{12} \cdot 4\frac{1}{2}H_2O$ |
| Harmotome | $RA_2Si_5O_{14} \cdot 5H_2O$ |
| Stilbite | $RA_2Si_6O_{16} \cdot 6H_2O$ |

The ratio of $RO:Al_2O_3$ is constant, 1:1, in the series, while the proportions of silica and water have a constant ratio, 1:1, between themselves, except in the case of phillipsite. As there is, however, considerable variation in the analyses of phillipsite, it is not improbable that the ratio of $SiO_2:H_2O$, given as $4:4\frac{1}{2}$, should be in some cases at least, $4:4$. The minerals then form a gradual series, increasing in the proportions of SiO_2 and H_2O from wellsite to stilbite.

Fresenius* has shown that this group of minerals may be regarded as a series in which the ratio of $RO:Al_2O_3$ is

*Zs. Kr., III, 42, 1878.

constant, 1:1, while the silica and water vary between certain limits. He has assumed as these two limits:



The first would be a hydrated calcium albite and the last a hydrated anorthite. From a comparison of the wellsite-stilbite series, it seems more probable that the anorthite end would be $RAl_2Si_4O_8 + 2H_2O$, or doubling this for better comparison with the formula of Fresenius $R_2Al_4Si_4O_{16} + 4H_2O$.

It is not unreasonable to expect that the first thite member of this series may be found in the completed series would then be:

Anorthite limit... $RAl_2Si_4O_8 + 2H_2O$ (not yet identified)

Wellsite $RAl_2Si_6O_{16}$

Phillipsite $RAl_2Si_8O_{20} + 10H_2O$ (perhaps $4H_2O$)

Harmotome $R_2Al_4Si_4O_{16}$

Stilbite $R_2Al_4Si_4O_{16} + 4H_2O$

It is also interesting to note that the formula of the new mineral wellsite is the same as that assigned to edingtonite, but the latter is essentially a barium mineral and being tetragonal shows no crystallographic relations to wellsite.

Pyrognostics.—When heated before the blowpipe, the mineral exfoliates slightly and fuses at 2.5-3 to a white bead, coloring the flame slightly yellow. In the closed tube, water is given off at a low temperature. It is very readily decomposed by hot hydrochloric acid with the separation of silica, but without gelatinization. When the water in the mineral is driven off below 265° C., it is nearly all regained on exposing the mineral to the air. If the water, however, is driven off at a red heat, none is regained by the mineral.

Name.—The name *Wellsite* is given to this mineral in honor of Professor H. L. Wells of the Sheffield Scientific School, Yale University.

CHABAZITE.

Occurrence.—As described on page 62, this mineral is intimately associated with the wellsite, at the Buck Creek Cullakanee corundum mine in Clay Co., occurring as a mass of small crystals coating the feldspar, hornblende and corundum. Thus far this mineral has been found only at the large open cut on the eastside of Buck Creek, just northwest of the shaft.

The crystals are transparent to white and very small, no crystal being found that measured over one millimeter in diameter.

The only form observed on any of these crystals was the unit rhombohedron, $10\bar{1}1$, which occurs as simple crystals and also as penetration-twins, with c , as the twinning axis.

Chemical analysis.—In obtaining material for analysis, the crystals of the chabazite and wellsite, freed as far as practicable from the feldspar and hornblende were crushed and sifted to a uniform grain. By means of the heavy solution, the chabazite was separated from the wellsite and also from any feldspar or hornblende that may have been attached to them. All of the chabazite floated, when the specific gravity of the solution was 2.278, while the wellsite and heavier minerals sank to the bottom of the separatory funnel. These were drawn off and the solution diluted to a specific gravity of 2.244, but only a small per cent. of the mineral sank. This being drawn off, the solution was further diluted to a specific gravity of 2.203, when nearly half of the remaining mineral sank. This was removed and saved for analysis, (II, below) and the solution again diluted. When the specific gravity had been lowered to 2.147, all, but a small amount of the mineral came down, and this was saved for analysis. (I) A preliminary experiment had been made with the crystals of the chabazite and these were found to vary considerably in specific gravity.

The mineral was analyzed by Dr. Chas. Baskerville* with the following results:

| I | | | II | | |
|---|-------|------|--------------|-------|------------|
| Sp. Gr. | | | Sp. Gr. | | |
| 2.147-2.203 | Ratio | | 2.203-2.244 | Ratio | |
| SiO ₂ .. 45.08 | .751 | | 3.79 46.15 | .769 | =3.79 |
| Al ₂ O ₃ .. 19.68 | .193 | | 1.00 20.74 | .203 | =1.00 |
| FeO .. 2.00 | .028 | | 2.00 | .028 | |
| CaO .. 7.22 | .129 | | .84 6.92 | .124 | |
| BaO .. .18 | .001 | .163 | .24 | .001 | .158 .77 |
| MgO .. .23 | .005 | | .22 | .005 | |
| K ₂ O .. 4.34 | .064 | | 4.10 | .043 | |
| Na ₂ O .. 3.35 | .054 | .100 | .50 3.35 | .054 | .097 = .47 |
| H ₂ O .. 18.00 | 1.000 | | = 5.02 16.30 | .905 | =4.46 |
| 100.08 | | | 100.02 | | |

The ratio of Al₂O₃ : SiO₂ : H₂O is near to 1 : 4 : 5 and Al₂O₃ : (R".K₂.Na₂)O is close to 4 : 5.

Usually in the composition of the chabazites the ratio of Al₂O₃ : (Ca . K₂ . Na₂)O is near to 1 : 1. In the present analysis, no attempt was made to separate any strontium present from the calcium. As a small amount of this element would cause considerable variation in the per cent of CaO, this would readily account for the excess of this oxide in the analysis.

The composition of the chabazite has always been somewhat uncertain as there is often a wide variation in the analyses of specimens from the same locality. The hypothesis advanced by Streng,[†] that the chabazite is an isomorphous mixture of



explains satisfactorily the variations observed in this

*Of the Chemical Laboratory, N. C. Geological Survey.

[†]Ber. Oberhess. Ges. 16, 74, 1877 and Dana Mineralogy, sixth edition, 1892, p. 591.

mineral. This is analogous to the composition of the albite-anorthite feldspars.

The approximate ratios deduced from the above analyses, of $\text{SiO}_2 : \text{Al}_2\text{O}_3 : (\text{Ca}.\text{Na}_2)\text{O} : \text{H}_2\text{O} = 4 : 1 : 1 : 5$, would give for the formula of this chabazite $m : n$, but with a low amount of water.

The variation in and the high specific gravity of the mineral is without doubt due to the varying proportions of barium and strontium in the molecule.

The occurrence of the chabazite at Buck Creek is interesting as being the only known locality of this mineral in North Carolina.

ANORTHITE.*

The occurrence of this feldspar at Buck Creek, Clay Co., N. C., has been described by J. V. Lewis.** The mineral forms with olivine a mass of forellenstin troctolite rock, outcropping over an area of about two acres, at the extreme eastern border of the peridotite outcrop. The particles of feldspar vary in size from that of a pea to some nodules that were an inch and a half long by three-quarters of an inch broad and are separated from the olivine by a zone of fibrous silicates, composed partly of enstatite.

The two cleavages are well developed in all the specimens of the mineral and in many of these the striations on the basal cleavage are very distinct.

The feldspar has suffered some kaolinization but the interior of the larger nodules is apparently free from all decomposition. By means of the heavy solution a product was obtained for analysis that varied in specific gravity from 2.6995 to 2.7440.

*Am. J. Sci. Vol. V, 1898, p. 128.

**N. C. Geological Survey, Bulletin 11, p. 24.

The results of the analysis made by Dr. Chas. Baskerville* are as follows:

| | | Ratio. | |
|--|-------|--------|-----------|
| SiO ₂ | 44.05 | .734 | 2.23 |
| Al ₂ O ₃ | 30.87 | .302 | .92 |
| FeO | .84 | .011 | |
| CaO | 17.30 | .308 | .328 1.00 |
| MgO | .36 | .09 | |
| Na ₂ O | 3.65 | .057 | |
| K ₂ O | .83 | .009 | |
| Moisture | .35 | | |
| Loss on ignition | 1.60 | | |
| | <hr/> | | |
| | 99.85 | | |

The ratio of SiO₂:Al₂O₃:CaO, is near to 2:1:1, which identifies the feldspar as an anorthite.

With the exception of a small amount of this mineral found at Shooting Creek, Clay Co., under similiar conditions, this is the only occurrence of anorthite in this State.

ANTHOPHYLLITE.

In 1890 Prof. S. L. Penfield† described this mineral which was reported as having come from the Jenks coumdum mine near Franklin, Macon Co., N. C.

During the summer of 1892, while engaged with the North Carolina Geological Survey, Prof. Penfield and the author visited an outcrop of dunite rock near Bakersville, Mitchell Co. On breaking open one of the loose boulders of decomposed dunite rock, *anthophyllite* was exposed, which Prof. Penfield at once recognized as identical with the specimen he had described.

As there has been no mention of the correct locality of

* Of the Chemical Laboratory N. C. Geological Survey.

†Am. J. Sci. XL, 1890, p. 394.

the anthophyllite and as this name is often applied to an enstatite occurring at the corundum mine, it has been thought that a description of the occurrence of these two minerals would be of interest.

At the Woody place two and a half miles south of Bakersville on the Marion road, there is a large outcrop of dunite rock extending from near the road to the top of the hill, a lenticular mass about 600 by 300 feet. The hillside, where it occurs, is quite barren and thickly scattered with loose fragments and boulders of the altered dunite. The outcrop has been carefully examined but the anthophyllite has only been found in the boulders. The mineral occurs in prismatic crystals imbedded in penninite. Nearly all the crystals are seamed and cracked while those near the outer part of the boulders are somewhat decomposed and stained a dirty brown. The purest crystals are transparent, and vary from pale clove brown to a flesh color.

The crystals measure from 2^{mm} to 6^{mm} in the widest diameter and in length, some were found that were over three centimeters.

A great many crystals were examined but no terminated ones were observed. The unit prism, 110, occurring alone, or in combination with the brachy pinacoid, 010, were the only forms observed.

Although the boulders containing the anthophyllite are composed almost always of this mineral and penninite, there are other minerals, resulting from the alternation of the chrysolite, which occur at this locality. These are magnetite in perfect octahedrons 1^{mm} in diameter, green actinolite, chalcedony, druzy quartz, talc, serpentine and genthite. Chromite occurs in grains in the chrysolite.

An analysis of the anthophyllite by Dr. Baskerville is given below, together with the results obtained by Prof. Penfield.*

| | I (Baskerville). | II (Penfield). |
|--------------------------------------|------------------|----------------|
| SiO ₂ | 56.40 | 57.98 |
| Al ₂ O ₃ | 1.15 | .63 |
| FeO..... | 11.40 | 10.39 |
| MnO..... | - - - | .31 |
| MgO..... | 28.68 | 28.69 |
| CaO..... | .50 | .20 |
| H ₂ O..... | 1.63 | 1.67 |
| Loss at 100°..... | - - - | .12 |
| | <u>99.76</u> | <u>99.99</u> |

The two analyses are very similar, and confirm Prof. Penfield's conclusion that the specimen described by him was from the Bakersville locality.

One specimen of a true anthophyllite was found at Corundum Hill by Prof. Penfield; but this was more fibrous and not of such good quality as that from the Bakersville locality.

ENSTATITE.

The enstatite from Corundum Hill that is commonly called anthophyllite, occurs as a rock composed of a mass of interlocking bladed grayish crystals of the mineral. The rock is very tough and tenacious and forms a perfectly continuous mass with the dunite. The outcrop of the dunite at Corundum Hill is very similar to that near Bakersville. The hill of nearly ten acres in extent has the dunite exposed over nearly its entire surface, and the enstatite is found at the lower south end of the outcrop in the zone of alteration products developed near the contact of the dunite with the hornblende gneiss.

*Am. J. Sci. XL, 1890, p. 396.

The analysis of this mineral by Dr. Baskerville* is as follows:

| | | Ratio |
|--------------------------------|-------------|-------|
| SiO ₂ | 51.64 | .861 |
| Al ₂ O ₃ | .12 | .001 |
| FeO | 9.28 | .129 |
| MnO | .56 | .008 |
| MgO | 31.93 | .798 |
| CaO | .45 | .008 |
| H ₂ O | 5.45 | .303 |
| | <hr/> 99.43 | |

It is evident from the amount of H₂O found, that the material analyzed was not pure, but was probably a mixture of the enstatite with serpentine and talc.

As is shown by the calculations below, the ratio in the above analysis would be satisfied by a mixture of 44.5 per cent. enstatite, 35 per cent. serpentine and 20.5 per cent. talc. The analysis is also given below after substituting for MnO and CaO their equivalents of MgO, deducting Al₂O₃ and recalculating to 100 per cent.

| 44.5 per cent. | | 35 per cent. | | 20 per cent. | | Recalculated |
|------------------------------|-------------|--------------|-------------|--------------|-------------|--------------|
| Enstatite. | Ratio. | Serpentine. | Ratio. | Talc. | Ratio. | Analysis. |
| SiO ₂ . . . 24.42 | .407 | 14.87 | .246 | 13.02 | .217 | 52.31 |
| FeO . . . 7.58 | .105 | 1.84 | .025 | --- | --- | 9.42 |
| MgO . . 12.50 | .312 | 13.83 | .346 | 6.51 | .163 | 32.84 |
| H ₂ O . . --- | | 4.46 | .246 | .97 | .054 | 5.43 |
| | <hr/> 44.50 | | <hr/> 35.00 | | <hr/> 20.50 | <hr/> 100.00 |
| | | | | | | 100.00 |

ENSTATITE (BRONZITE.)

The occurrence of this mineral in any considerable amount in North Carolina was first mentioned by Dr. G. H. Williams** who described specimens of a bronzite-dio-
 opside rock, to which he gave the name websterite.

*N. C. Geol. Survey, Bull. 11, p. 27.

**American Geologist VI, pp. 43-4, 1890.

†J. V. Lewis N. C. Geol. Survey, Bull. 11, p. 27.

These specimens were collected near Webster, Jackson Co., by Mr. Geo. P. Merrill of the U. S. National Museum.

On the road from Webster, following up the Tuckasegee river valley and about one half mile from the town, a mass of dunite[†] is exposed for over 1500 feet on a hillside facing the river. In the midst of this outcrop, the websterite occupies a width of nearly 300 feet. This outcrop of dunite is very similar to that near Bakersville and at Coumdum Hill, described above.

This rock as described by Williams,* is composed entirely of bronzite and an emerald-green diopside. The ground mass of this rock is composed of the brilliant green grains of the diopside through which rounded crystals of the pale brown bronzite are disseminated. The relative amount of the bronzite is variable as it shows a tendency to concentrate in nests or bands.

Lewis** speaks of this rock as a compact granular rock closely resembling the dunite with which it is associated.

Near the north end of the dunite outcrop, at the side of the road, boulders were observed, which when broken open were found to be composed almost entirely of bronzite. Besides the boulders a mass of the same rock was observed apparently *in situ*.

The bronzite composing this rock is of a resinous brown color, and of a bronze like luster, even on the unaltered surfaces. On the cleavage surface the luster is decidedly pearly. No distinct crystals were observed, the specimens being a mass of interlocking crystals making a very tough rock similar to the enstatite described above. In most of the specimens, the crystals were so interlocked that no crystal outline of these could be distinguished. In a few of the specimens the crystals were much larger

*American Geologist VI. pp. 43--4. 1890.

**N. C. Geol. Survey Bull. 11. p. 27.

in their development and their outline could readily be detected. Some of the crystals measured 2^{cm} in the direction of the *b*, axis.

Associated with the bronzite is the emerald-green diopside mentioned by Williams, which is sparingly scattered through the rock in very small, clear, green grains.

While the websterite is composed of a base of diopside grains with the rather large rounded crystals of the bronzite penetrating through it, the bronzite rock is essentially interlocking prismatic crystals of the bronzite with a few grains of the diopside disseminated through it. This rock, also, does not show any of the granular character of the websterite; but on the contrary it is very compact and tough.

The material for analysis was hand picked and that selected showed no impurities or decomposition when examined with the magnifying glass.

The results of the analysis by Dr. Baskerville are given below:

| | | Ratio | |
|--------------------------------------|-------|-------|--------------|
| SiO ₂ | 53.62 | .894 | =1. |
| Al ₂ O ₃ | .97 | .009 |) .012 |
| Cr ₂ O ₃ | .50 | .003 | |
| FeO | 9.06 | .125 |) .994 =1.11 |
| CaO | 1.75 | .031 | |
| MgO | 33.53 | .838 | |
| H ₂ O | .19 | | |
| | 99.62 | | |

In the above analysis the ratio of the bivalent oxides to silica is close to 1 : 1, and of ferrous oxide to magnesia and lime is very near to 1 : 7; this would give the formula (MgFe)SiO₃ with Mg : Fe=7 : 1. Assuming that the Al₂O₃ and Cr₂O₃ belong to spinel and deducting RO sufficient to combine with them, the analysis, after substituting for CaO its equivalent of MgO and recalculating to

100 per cent, is given below together with the theoretical composition calculated for this formula.

| | Found | Theory for (MgFe)SiO ₃ ; Mg : Fe=7 : 1 |
|----------------------------|--------|--|
| SiO ₂ | 55.35 | 57.69 |
| FeO | 9.14 | 8.65 |
| MgO | 35.51 | 33.66 |
| | <hr/> | <hr/> |
| | 100.00 | 100.00 |

The name bronzite is very appropriate to this Webster enstatite, for the luster is of a decided bronze-like character throughout the entire mass and is undoubtedly not of a secondary origin, but is the natural luster of this mineral. A similar bronzite, showing the same decided bronze-like luster has been found at the Buck Creek, (Cullakanee,) corundum mine in Clay county.

EMERALD BERYL.

Although the beryl is a very common accessory mineral, in granite veins, especially those of a pegmatitic character, it is not common to find the deep emerald green variety. The earliest report of the emerald in North Carolina is 1880, by W. E. Hidden* who describes the occurrence in Sharpes Township, Alexander Co. where it is found associated with the emerald green hiddenite.

The occurrence of the emerald in Mitchell Co. has been known since 1886, though but little work has been done to develop the locality and to estimate its economic value. The mineral is found on the divide between Brush and Crabtree Creeks about four miles south of Spruce Pine, post office.

The vein carrying the beryl is of a pegmatitic character consisting chiefly of quartz and an albite feldspar, with

*Elisha Mitchell Scientific Society. 1880.

tourmaline, garnet and the beryl as accessory minerals. The country rock is a gneiss and biotite schist.

The emerald beryl has the characteristic green color of the gem and some of the crystals are transparent. They all have the hexagonal prism well developed, but none were observed that showed any terminations. The crystals vary in size from less than a millimeter up to eight millimeters in diameter. They are found imbedded in the quartz, feldspar and biotite schist, but are for the most part near the contact of the vein with the schist. The most transparent and deepest green crystals observed were either entirely surrounded by the schist or close to the contact. Those in the quartz were usually more transparent than those found imbedded in the feldspar. The color of the crystals varies with their location in the vein, those nearest the schist being of the emerald variety, while those farther away are pale green or yellow.

The yellow or cream colored beryls are very abundant though the vein. The crystals vary considerably in size, from those hardly 2^{mm} in diameter to one that measured 17^{cm}.

The locality as yet has not been developed sufficiently to demonstrate whether it will warrant its being worked for gems. Both Col. Rorison of Bakersville, and Capt. Isaac English of Spruce Pine report that crystals have been found from which good gems were cut.

GRASS GREEN CYANITE.*

The mineral to be described occurs on the farm of Tiel Young, near North Toe River, Yancey Co., North Carolina, a few miles from Spruce Pine, Mitchell Co.

Some exceptionally large crystals of a grass-green color were obtained by the author during the summer of

*Am. J. Sci. Vol. V. 1898, p. 126.

1896 from Mr. M. Alexander, a jeweler in Asheville. After some difficulty the occurrence was located, during the summer of 1897, and the locality has been thoroughly worked by Geo. L. English & Co. of New York, with the result that many good crystals of the cyanite have been obtained.

The mineral occurs in a decomposed mica schist from which the single crystals are easily separated. The crystals are often intergrown and masses of these were obtained as large as one's two fists. All of the crystals found were of a rich grass-green color and many were quite transparent. A few of the crystals showed a deep blue center with the grass-green margins. The crystals vary in size from $1 \times .7\text{cm}$ to $3.2 \times 6\text{cm}$; a few coarser ones were observed that were considerably larger. The finest crystal that has been found at this locality measured $5.8 \times 2.2 \times 1.8\text{cm}$ and was perfectly transparent at one end for about 2cm . The three pinacoids were the only faces observed on this crystal and these were evenly and well developed. This crystal is now in the Brush Collection at New Haven, Conn. The faces are generally smooth, giving fair reflections of the signal on the reflecting goniometer.

The forms observed on these crystals are as follows.

| | | | |
|---------|--------|----------------------|--------|
| c, 001. | a, 100 | M, $\bar{1}\bar{1}0$ | |
| b, 010 | m, 110 | Q, 120 | l, 520 |

The face 520 is apparently a new one for cyanite. The three pinacoids were the only faces observed on the majority of the crystals, some of which were doubly terminated. After a very careful examination of the terminations, they were decided to be real basal planes and not cleavage surfaces. On one of the crystals, all of the faces observed were developed.

The following table shows the identification of the forms by calculated and measured angles. In obtaining the calculated angles the elements given in Dana's Min-

eralogy (1892), deduced from Rath's measurements* on Greiner crystals, have been used.

$$a:b:c = 0.89938:1:0.70896; \alpha = 90^\circ 51'; \beta = 101^\circ 21'; \gamma = 105^\circ 44\frac{1}{2}'$$

| | Calculated. | Measured. |
|--------------------------------|-------------|-----------------------|
| $a\Delta m$, 100 Δ 110 | 34° 17' | 34° 17'; 34° 20'; |
| $a\Delta M$, 100 Δ 110 | 48 18 | 48 43; 48 41; 48° 45' |
| $a\Delta Q$, 100 Δ 120 | 48 43 | 48 50 |
| $a\Delta L$, 100 Δ 520 | 17 9 | 17 13 |
| $a\Delta h$, 100 Δ 010 | 73 56 | 73 40; 73 38; 73 42 |
| $b\Delta M$, 010 Δ 110 | 57 46 | 57 41 |

The specific gravity is 3.64 and was determined upon several different samples. Pleochroism is very strong.

Iron and chromium were very carefully tested for, but no trace of either was observed in the analysis, which showed only the presence of alumina and silica.

Crystallized cyanite is usually in long bladed crystals without terminations, the best crystals having been found at St. Gothard in Switzerland and on Mt. Greiner in Tyrol. These crystals of a blue and blueish white color, are often transparent but are seldom over a few millimeters wide.

This new occurrence of the cyanite is not only of interest on account of the deep green color of the mineral but also on account of the exceptional size and development of the crystals.

Pale green cyanite has been obtained from a number of localities and it has also been found in the vicinity of the green cyanite locality on the farm of Isaac English of Spruce Pine, Mitchell Co., imbedded in an undecomposed mica schist. Another occurrence that is worthy of note is that of Graves Mt., Georgia. At this locality thin small plates of the pale green cyanite are associated with well crystallized rutile.

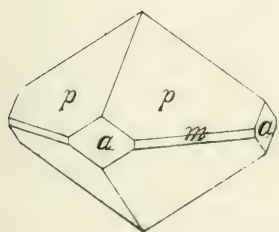
*Zs. Kr., v, 17, 1880.

ZIRCON.

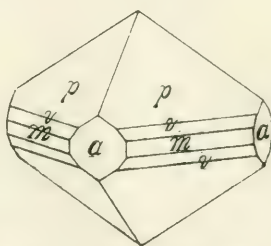
Some specimens of zircon crystals were obtained of Messrs. Geo L. English & Co., from New Stirling, Ireland o., CNorth Carolina, and on account of their size and development it has been thought a description of them would be of interest.

The crystals are all very similar in their habit, in which the unit pyramid is strongly developed while the prisms faces are short, figs. 4 and 5. Fig. 4 represents the majority of the crystals, where the prism of the first order is only slightly developed, at times being hardly perceptible. Those represented by fig. 5 are similar in their habit to some zircon crystals described by the au-

4.



5.



thor from the townships of Dungannon and Faraday, Ontario.[†]

The following forms were observed on these crystals:

a , 100; m , 110; p , 111; v , 221; x , 311.

The face x , 311 was only observed on a very few of the crystals and was but slightly developed. The crystals are all well developed with smooth faces, making them well adapted for measurement on the reflecting goniometer. Although the author had no reflecting goniometer at hand, the faces were readily identified by means of the contact goniometer.

The crystals vary in size from 1^{cm} to 2.5^{cm} in diameter and are of a reddish-brown color.

*Am. J. Sci. Vol. V, 1898, p. 127.

†Am. Jour. Sci., vol., xlviii, p. 215, 1894.

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FIFTEENTH YEAR—PART ONE.

1898.

THE NATURE OF THE CHANGE FROM VIOLET
TO GREEN IN SOLUTIONS OF CHROM-
IUM SALTS.

BY F. P. VENABLE AND F. W. MILLER.

It is a well-known fact that solutions of certain chromium salts which are violet in color become green on heating. This has been especially noticed in the case of the chrome-alums and of the sulphate, but is also true of the nitrate, chloride, and acetate, in fact, of all the soluble compounds of chromium. A reverse reaction also takes place and all of these solutions made green by heating become violet again on standing, the nitrate, chloride, and acetate very rapidly, the sulphate and alums slowly, and often only after prolonged standing. It is quite reasonable to suppose that these changes are caused by similar reactions in the case of various salts, and that there is one explanation for all.

A large number of explanations have been offered by various investigators. In fact it is surprising to find how many have been drawn to investigate these changes and what an amount of work has been done upon them. Perhaps the difficult nature of the problem has been the great source of attraction. Fischer¹ and Jacquelin²

¹ Kastner's *Archiv.*, 14, 164.

² *Compt. rend.*, 24, 439.

have attributed these changes to a separation of the chromium sulphate from the alkaline sulphate: Berzelius¹ and Fremy² assigned as the cause of the changes the formation of a basic sulphate; Recoura and Whitney³ and Dougal⁴ have considered the true cause to be the formation of a chrom-sulphuric acid; Schrötter⁵ suggested a partial dehydration, and Etard⁶ also thought the change due to an alteration in hydration; Roscoe and Schorlemmer⁷ regarded the green solutions as containing mixtures of basic and acid salts; Loewel⁸ advanced the theory of an isomeric change.

It is quite manifest that any theory like that of Fischer and Jacquelin, based upon an examination of the alums alone, is quite inadequate. It is further evident that any phenomenon which has aroused so great a variety of speculations as this must be considered very carefully with due weighing of every known fact. These facts are numerous and important.

HOW THE CHANGE MAY BE BROUGHT ABOUT.

Chrome-alum is soluble in six parts of water; the violet solution suffers the alum slowly to crystallize out unchanged by spontaneous evaporation; but if heated to between 50° and 75° it turns green and, according to the extent of decomposition, either deposits on evaporation a brilliant, green, amorphous, difficultly soluble mass, or "yields crystals of sulphate of potash, leaving green sulphate of chromic oxide in solution."⁹

Schrötter says the change takes place at 65°–70°. He

¹ *Ann. Phys. Chem.*, 61, 1.

² *Compt. rend.*, 47, 883.

³ *Ztschr. phys. Chem.*, 1896, 20, 40.

⁴ *J. Chem. Soc.*, Lond., 1896, 69, 1526.

⁵ *Pogg. Ann.*, 53, 513.

⁶ *Compt. rend.*, 84, 1090.

⁷ *Treatise on Chemistry*, First Edition, Vol. II, Pt. II, 163.

⁸ *J. d. Pharm.* (3), 7, 321.

⁹ Fischer, cited in Gmelin: *Handbuch*, 1850, IV, 149.

further states that the crystals of potassium sulphate separate only from a highly concentrated solution and in small quantity. Sprung has shown, in experiments to be quoted later, that the change begins at a temperature under 30° .

We have repeatedly attempted to secure the separation of crystals of potassium sulphate as described by Fischer and Schrötter, but without success. The exact conditions are clearly difficult to hit upon, if such a separation is at all possible.

Alkaline hydroxides and carbonates, according to van Cleeff,¹ turn violet solutions of the alums green, and Etard² has shown that they bring about the same change in solutions of the normal sulphate. Sulphuric acid, phosphorus trichloride, and nitric acid, according to Etard, bring about the same change, but Otto³ says that sulphuric acid does not turn solutions of the alum green if rise of temperature is prevented. Schrötter says that nitric acid turns green solutions of chromium sulphate blue again.

Our experiments along this line resulted as follows: First as to the action of acids. Hydrochloric acid had no action upon either violet or green solutions, nor does it apparently have any influence upon the change from one to the other on heating. Sulphuric acid brought about no change in either in the cold, but has a retarding influence upon the change on heating. This was so marked in one or two experiments that it was thought the change would be entirely prevented. Nitric acid had no appreciable immediate effect upon either in the cold. On heating with the violet the retarding action was greater than when sulphuric acid was used, and the solution resumed its violet color on cooling. Acetic acid had

¹ *J. prakt. Chem.* (2), 23, 58.

² *Compt. rend.*, 84, 1090.

³ Graham-Otto, 4 Aufl., 3, 113.

apparently no influence. As to the action of alkalies, sodium or potassium, or ammonium hydroxide, or the carbonates, readily turned the violet solutions green. They had no action upon green solutions.

CHANGES IN PHYSICAL PROPERTIES.

In the case of chromic sulphate, Sprung¹ has shown that the violet solution with about twenty-four per cent. of the salt has the specific gravity 1.1619, while the green is 1.1486. So too with the alum there is an increase of volume, which has been noticed by Siewert and also by Mohr,² and a decrease of volume is observed as the green solution reverts to the violet. Lecoq de Boisbaudran³ has also observed these changes, noting that they are independent of the concentration of the solution, the presence of crystals, or whether the vessel is open or closed. The changes in density can be reckoned from his dilatometric observations. Dougal⁴ has shown that the alteration in density of even a dilute solution of chrome-alum, after boiling, may readily be detected by a specific gravity bottle. In this manner, one, two and a half, and five per cent. solutions were experimented upon. The actual amount of change depended upon the duration of the heating and the length of time which had elapsed since the green solution had been prepared. The violet solutions became specifically lighter when changed to green by boiling. The transformation is accompanied therefore by expansion.

According to Sprung the violet and green solutions show a difference in internal friction or viscosity. The ratios of diffusion out of capillaries at temperatures 10°, 20°, 30°, 40°, 50°, of the green to the violet were as 100

¹ *N. Arch. ph. nat.*, 53, 112.

² *Ber. d. chem. Ges.*, 4, 318.

³ *Compt. rend.*, 79, 1491.

⁴ *J. Chem. Soc. Lond.*, 1896, 69, 1597.

to 60.70 ; to 67.77 ; to 68.74 ; to 70.79 ; to 75.72. From this it is seen that the change begins at less than 30° , and from this arises the observation that has been made that the solution of the alum turns somewhat green at ordinary temperatures.

The diffusion of these solutions has also been carefully studied with a view to throwing light upon this puzzling problem.

With regard to the sulphate it has been shown by van Cleeff¹ that green solutions on being dialyzed yield dialysates containing a larger proportion of acids. This had been repeatedly investigated in the case of the alum. Thus van Cleeff has found that in the dialysis of the green solution of the alum, relatively more sulphuric acid goes into the dialysate than when the violet solution is dialyzed. Dougal² has also carried out careful experiments along this line. Time, temperature, strength of the dialysate, amount of initial change, amount of retrogression, all affected the results, and little beyond the facts stated above could be deduced from them. The experiments were made upon solutions containing one per cent. of the alum. While the author states that no comparison could justly be made between the experiments, it may be noted that the ratio of increase in acidity was fairly regular and ranged between one-seventh and one-sixth.

A few experiments were undertaken upon the dialysis of the alum before Dougal's experiments were known to us. They were not pushed to completion when these latter became known, especially as there seemed little chance of their throwing much light upon the nature of the change.

CHANGES IN CHEMICAL PROPERTIES.

One of the most singular changes in chemical proper-

¹*J. prakt. Chem.* (2), 23, 58.

²*J. Chem. Soc. Lond.*, 1896, 69, 1527.

ties is that noted in the action of the sulphate or alum, before and after heating, upon solutions of barium or lead salts. This was first observed by Loewel¹ and was studied by Favre and Valson.² A violet solution on being treated in the cold with a solution of barium chloride, yields practically all of its sulphuric acid as barium sulphate. A cold green solution forms a precipitate slowly, and even after a number of hours the precipitation is far from complete. On boiling, all of the sulphuric acid will be precipitated. Favre and Valson found that only one-third of the sulphuric acid present in the original chromic sulphate was precipitated in the cold by the barium chloride.

Our own experiments upon this point were as follows: A weighed amount of the pure alum was dissolved and the solution made up to a definite quantity. Two aliquot portions were taken, one of which was heated for half an hour and allowed to cool. Then both portions were precipitated with an excess of barium chloride. It was found impossible to filter these immediately with asbestos felts or the best filter-paper. They were therefore allowed to stand about twenty-four hours. This very long standing probably changed the conditions somewhat, but we were unable to avoid it. Still the results would confirm the observations of Favre and Valson. The prolonged standing also showed that it was not merely a delayed precipitation, but one partially prevented.

| | I. | II. |
|---|-------|-------|
| Percentage of SO_3 in alum is 32.06..... | ..... | ..... |
| Percentage of SO_3 in alum, violet solution precipitated cold..... | 30.44 | 30.19 |
| Percentage of SO_3 in alum, green solution heated one-half hour..... | 22.75 | 22.33 |
| Percentage of SO_3 in alum, green solution heated one hour..... | 22.87 | 21.83 |

¹ *J. Pharm.* (3), 4, 32.

² *Compt. rend.*, 77, 803.

These experiments were upon solutions containing one gram to 100' cc. A solution twice as strong was next taken:

| | I. | II. |
|---|-------|-------|
| Percentage in violet solution precipitated cold..... | 28.88 | 31.80 |
| Percentage in green solution (heated one hour) precipitated cold..... | 19.55 | 21.47 |

Again a solution containing 0.5 gram to the 100 cc. was taken.

| | |
|---|-------|
| Percentage in violet solution precipitated cold..... | 28.30 |
| Percentage in green solution (heated one hour) precipitated cold..... | 23.00 |

The difficulties of washing and filtering barium sulphate precipitated in this manner account in part for the lack of agreement between the analyses, but two things are evident; first, that all the sulphuric acid is not precipitated from either violet or green solutions in the cold, and, secondly, that a short boiling effects such a change that only two-thirds of the sulphuric acid is precipitated by barium chloride in the cold. The amount not precipitated ranged from 9.06 to 13.51 per cent.

Many observations have been recorded as to the acidity of the violet and green solutions of the alum. Recoura¹ has stated that the vapors coming from a solution at 100° are acid, while the solid salt at the same temperature does not lose any acid. He further maintains that the green solution, left after the heating, contains a considerable amount of free acid. He made use of the heat of neutralization as a means of measuring the degree of acidity. A known amount of soda was added to the liquid and the heat liberated was measured. In so far as this corresponds with the heat liberated by the neutralization of free sulphuric acid in the same degree of dilution, he concluded that he was dealing with free acid. According to his

¹ *Compt. rend.*, 112, 1440.

² *Ann. Phys. Chem.* (3) 61, 218.

experiments there was one-half of an equivalent of sulphuric acid for every equivalent of chromium sulphate.

It was Kruger¹ who first attempted to show in 1844 the presence of free sulphuric acid in the green solution. He thought this was proved by the acidity of the layer of alcohol poured over the green solution.

Baubigny and Pechard² have shown that the alum has always an acid reaction even after purification by means of alcohol. Further they regarded the following experiment as proving a partial dissociation of the salt. To twenty cc. of a saturated solution of the alum, three-tenths gram of ammonia gas was added, and, after shaking, the liquid was neutral to methyl orange; after some time the liquid which had become green on the addition of the ammonia, yielded violet crystals with strong acid-reaction and the mother-liquor had become acid to methyl orange.

Whitney³ has also attempted to prove the presence of acid by physical methods. Sodium hydroxide and barium hydroxide respectively were added to the green solution. The addition of a base must lower the conductivity of the solution as long as free sulphuric acid is being neutralized. He found the minimum when he had added one-sixth of an equivalent of sodium hydroxide to the chromium sulphate, or one-third of an equivalent of barium hydroxide. No explanation was given of the variation in the results. He also claimed⁴ to have proved the presence of free acid by the catalysis of methyl acetate. Lastly, the inverting action of green solutions of chromium chloride, acetate, nitrate, and sulphate was tried upon sugar solutions. He came to the conclusion that in the case of the chloride and nitrate, two-thirds of the acid was set free on boiling; of the acetate more than two-thirds, and of the sulphate less than one third. In our own experiments as to the relative

¹ *Compt. rend.*, 115, 604.

² *Ztschr. phys. Chem.*, 1896, 20, 40.

acidity of the violet and green solutions, it was seen that both solutions were acid. We tried a large number of the usual indicators, but the violet and green colors of the solutions interfered too much to give any results with them which could be regarded as at all satisfactory. It was found that fair results could be obtained by using a decinormal solution of ammonia and noting the first appearance of a permanent precipitate.

| | Tenth-normal ammonia. |
|--|--------------------------|
| | cc. |
| One gram in 100 cc. cold required..... | 27.5 |
| “ “ “ “ “ boiled one-half hour..... | 27.6 |
| “ “ “ “ “ “ one hour..... | 26.5 |
| “ “ “ “ “ “ two hours..... | 26.5 |

During the boiling, the water evaporated was repeatedly restored. Unless this was done a little acid was lost, and even with this precaution there was a small loss, and this may explain the acidity of the vapors coming off at at 100° as observed by Recoaru.

The experiments therefore agree with those of Baubigny and Pechard, but are at variance with the conclusions of the other authors mentioned. We think the experimental data of these authors do not afford sufficient and satisfactory evidence to serve as a basis for their conclusions that free sulphuric acid exists in the solution. The methods adopted are very indirect and the results capable of other explanations.

THE EXISTENCE OF CHROMO-SULPHURIC ACIDS.

Several articles have been published by Recoura¹ upon chromo-sulphuric acids. He claims to have prepared several of these and regards the formation of such bodies as a probable explanation of the change in the green solutions, and others, as Whitney and Dougal, seem to accept his explanation. Recoura thinks there are two isomeric modifications of chromium sulphate; one violet, one green, and also another green sulphate not isomeric,

but basic $2\text{Cr}_2\text{O}_3 \cdot 5\text{SO}_3$. These he refers to three conditions of chromic hydroxide: $\text{Cr}_2(\text{OH})_6$, precipitated by alkalis from violet chromic salts; $\text{Cr}_2\text{O}(\text{OH})_4$, corresponding to the basic sulphate and non-isolable; $\text{Cr}_2\text{O}(\text{OH})_4$, precipitated by alkalis from green solutions. Solutions of this latter in acids, he says, are not precipitated by solutions of barium salts. This last statement is not strictly true. Such solutions are partially precipitated by barium salts just as all green solutions are. He assigns to the green sulphate the formula $\text{Cr}_2\text{O}_3 \cdot 3\text{SO}_3 \cdot 11\text{H}_2\text{O}$, which he says has quite a different constitution from that of the violet sulphate. Proofs for this statement he does not give. This isomeric green sulphate, he says, possesses neither the characteristics of a sulphate nor of a chromium salt. One molecule can combine with one molecule of either sulphuric acid or a metallic sulphate. Thus we may have $\text{Cr}_2\text{SO}_4 \cdot \text{H}_2\text{SO}_4$ or $\text{Cr}_2\text{SO}_4 \cdot \text{K}_2\text{SO}_4$. In these compounds all the sulphuric acid is in a non-precipitable form, he maintains. His crucial experiment is as follows:

“Mix a solution containing one molecule of Cr_2SO_4 with a solution containing one molecule of sulphuric acid or a sulphate. Union is immediate, for barium chloride will now give no precipitate and the solution therefore holds no sulphate. The new radical is unstable, for precipitation is immediate on boiling, or in concentrated solutions or in dilute solutions on standing one-half hour. *It is necessary to work with very dilute solutions, otherwise the radical containing chromium is decomposed.*”

Of course such reasoning would give us these same strange isomeric metal-sulphuric acids in all sulphates, for if they are diluted enough it will take half an hour or more for the precipitate to form with barium chloride.

On such slender basis Recoura builds up a series of salts of a hypothetical chromo-sulphuric acid $(\text{Cr}_2 \cdot 4\text{SO}_3)_x$.

He has also prepared a chromo-disulphuric acid, etc., by evaporating solutions of chromium sulphate with two, three, etc., molecules of sulphuric acid; and then heating to 110°–120°. Calvert and Ewart¹ have shown that, on diluting these, they all leave a colloidal $\text{Cr}_2(\text{SO}_4)_3 \cdot \text{H}_2\text{SO}_4$ upon the septum, the liquid passing through free of chromium. The behavior of these solutions makes it appear probable that the chromo-sulphuric acids do not exist in them as such, but are hydrolyzed, forming the colloidal substance, $\text{Cr}_2(\text{SO}_4)_3 \cdot \text{H}_2\text{SO}_4$, and free sulphuric acid. Our repeated experiments have failed to show the presence of this colloidal body in the ordinary green solutions of the alum or sulphate. A boiled solution of either, even though very concentrated, will pass entirely through an unglazed porcelain suction filter, such as Calvert and Ewart made use of. There seems to be no colloidal body present.

We cannot regard the experiments of Recoura as advancing the subject in any degree. As an explanation of the changes it is by no means satisfactory. Dougal's formula for the reaction causing the change, is even more remarkable and baseless :



This is not based upon Dougal's own experiments but is offered as an explanation deduced from the work of Recoura, Whitney, Favre, and Valson.

THE ACTION OF ALCOHOL.

There have been several investigations of the action of alcohol, both upon the sulphate and the alum, with the hope of throwing some light upon the changes under consideration. Traube² states that the solid salt is unaffected by boiling alcohol. Schrötter has observed³ that

¹ *Chem. News*, 74, 121.

² *Hann. Chem.* (Liebig), 66, 168.

³ *Pogg. Ann.*, 53, 413.

solutions covered with a layer of alcohol become gradually green and the concentrated green solution is not dissolved by alcohol. Of course the first observation does not necessarily connect the alcohol with the change. Alcohol in large amounts precipitates from violet solutions of the sulphate a pale violet colored, crystalline powder, and decolorizes the liquid.¹ This can be used as a mode of purifying the alum.² Siewert³ states that, when the violet sulphate is dissolved in a small amount of water and boiled with alcohol until the crystals formed are again taken up and then precipitated with ether, a green syrup is gotten which consists of $5\text{Cr}_2\text{O}_3 \cdot 12\text{SO}_3 \cdot x\text{H}_2\text{O}$ and the mother-liquor contains sulphuric acid in a condition in which it is not precipitated by barium chloride. Krüger⁴ states that alcohol precipitates from a green solution of the alum a green oil which solidifies and which contains only two-thirds of the sulphuric acid. Siewert confirms this and says that this substance has approximately the composition $6\text{K}_2\text{O} \cdot 5\text{Cr}_2\text{O}_3 \cdot 18\text{SO}_3 \cdot \text{H}_2\text{O}$. Krüger mentioned the acidity of the alcohol used in precipitating the green oily liquid and evidently regarded it as withdrawing sulphuric acid from the original salt. He also mentioned the formation of a basic salt, by heating the green solution until it becomes rose-red, which contains half as much acid as the neutral salt and is insoluble in water.

After a careful consideration of the results obtained by others by means of alcohol, it seemed to us quite possible that these might afford a clue to the explanation we were in search of. It was necessary to examine with care the action upon both the violet and the green solutions. Our experiments are therefore given in detail, and it will be

¹ Gmelin's *Handbuch*, IV, 127.

² Baugigny and Pechard : *Loc. cit.*

³ *Ann. Chem.* (Liebig), 125, 97.

⁴ *Ann. Phys. Chem.*, 61, 318.

seen that they agree in part only with the observations just quoted.

Action on the Violet Solution.—When alcohol was added to the violet solution of alum, fine violet crystals were precipitated, which gave on analysis the following results:

| | Calculated for | Found. | |
|-----------------------|----------------------------------|--------|-------|
| | $K_2Cr_2(SO_4)_4 \cdot 12H_2O$. | I. | II. |
| Cr..... | 13.32 | 13.68 | 13.36 |
| K..... | 9.99 | 9.80 | ... |
| SO ₄ | 49.99 | 48.85 | ... |

This may be an old observation that on crystallizing from alcohol the crystals contain only half the usual amount of water, but we have not met with it anywhere. The fact that this very considerable change of hydration effects no change in color nor in the precipitating power of barium chloride, argues against the partial dehydration theory of Schrötter and Etard. It should be added that the precipitation was carried out with absolute alcohol upon concentrated solutions of the alum, was rapid, and the precipitate was immediately removed. There seemed to be two layers of crystals, one of violet crystals (upper) and the other a heliotrope powder. Analysis showed that the composition of both was the same and that the difference was probably one of subdivision. The precipitation is almost complete, as the alcohol shows very little color. From this it is evident that alcohol itself does not materially affect the violet solutions.

Action on the Green Solutions.—Green solutions of the alum were first experimented with. When absolute alcohol is added to concentrated solutions of chrome alum, which have been boiled until green and allowed to cool, a dark green gummy mass separates out after a short time. If the boiling is not sufficiently prolonged there will form afterwards a few violet crystals. The alcohol retains something in solution, as is shown by the green color. This amount retained may be considerable if much water

is present. It would seem then, that alcohol precipitates out the body and makes it available for analysis and examination. If a portion of this green, gummy mass is taken and dissolved in water, it exhibits the same behavior towards barium chloride as has been observed in the green solutions. In one or two cases it was observed that the part remaining dissolved in the alcohol yielded practically all of its sulphuric acid to barium chloride in the cold. The green mass was thoroughly washed with alcohol and dried over sulphuric acid. It also dries to a brittle mass if exposed in thin layers to the atmosphere. It is quite insoluble in alcohol, but soluble in water. A number of preparations of this substance were made and analyzed and the results are in such agreement that one is inclined to believe that the substance is a definite compound.

Fifteen grams of chrome alum were dissolved in 100 cc. water and boiled for one hour to a concentration of fifty cc. This was cooled and precipitated by the addition of 100 cc. of absolute alcohol. The green mass obtained on drying weighed about eight grams. This was carefully analyzed :

| Calculated for | | Found. | | | |
|---|-------|--------|-------|-------|-------|
| $7K_2SO_4 \cdot 5Cr_2(SO_4)_3 \cdot Cr_2(OH)_6 \cdot 4H_2O$ | | I. | II. | III. | IV. |
| Cr..... | 18.07 | 18.23 | 18.32 | 18.02 | 17.76 |
| K..... | 15.88 | 15.18 | 15.63 | 15.78 | .... |
| SO ₄ | 61.08 | 60.55 | 60.73 | .... | 60.79 |

Analysis III and IV were from other preparations, made, however, in a similar manner to that just described. This substance appears to have quite a complicated constitution, and it is not easy to see the part played by the potassium sulphate. It does not seem to be a matter of accidental occurrence, however. The important feature is that the salt is a basic one. Siewert gives, as the result of his analysis, $6K_2O \cdot 5Cr_2O_3 \cdot 18SO_3 \cdot H_2O$, for which the following percentages would be required: Cr, 18.7; K, 16.8; SO₄, 61.9. While these percentages differ somewhat from those obtained by us, the agreement is suffi-

cently close to show that the substances examined were practically the same.

On concentrating the liquid poured off from the green gum, it was repeatedly observed that more of the gum was obtained. For instance, in the experiment described where the green mass from fifteen grams weighed about eight grams, a further portion weighing 0.3915 gram was gotten. The analysis of this yielded the following percentages: Cr, 13.66; K, 8.57; and SO_4 , 55.45. We could only regard this as a mixture consisting in part of the green basic mass which had not completely separated out. The small amount of material left in solution (less than one-half gram) consisted of a little chromium with sulphuric acid in the ratio of about five to one.

Next the action on chromium sulphate was examined. The chromium sulphate used was in the form of small violet scales or crystals. It was a commercial product and the method of its preparation was unknown to us. An analysis of it gave:

| | |
|---------------------|--------|
| Cr..... | 22.10. |
| SO_4 | 44.20. |

It is therefore a basic chromate, but we have seen no such body described in the books. It dissolved in water with a green color. Fifteen grams of this dissolved in 100 cc. of water, boiled to a concentration of 50 cc. and precipitated with 100 cc. of alcohol, yielded about ten grams of the green, gummy mass, very similar in appearance to that obtained from the alum, but more soluble in alcohol. In a second experiment twelve grams were taken and treated in the same way, and yielded about eight grams. The analysis showed these to be identical.

| Calculated for | | Found. | | |
|--|-------|--------|-------|-------|
| $\text{Cr}_2(\text{SO}_4)_3 \cdot \text{Cr}_2(\text{OH})_6 \cdot 15\text{H}_2\text{O}$. | | I. | II. | III. |
| Cr..... | 24.06 | 22.41 | 22.40 | 22.69 |
| SO_4 | 33.17 | 34.64 | 34.73 | 34.43 |
| Water..... | 43.77 | ..... | ..... | ..... |

The agreement is far from satisfactory, but the body is evidently a basic salt.

On evaporating the liquid portions other masses were obtained. These were also analyzed :

| Calculated for | | Found. | | |
|---|-------|--------|-------|-------|
| $2\text{Cr}_2(\text{SO}_4)_3 \cdot \text{Cr}_2(\text{OH})_6 \cdot 20\text{H}_2\text{O}$ | | I. | II. | III. |
| Cr..... | 22.70 | 22.93 | 22.71 | 22.98 |
| SO_4 | 42.72 | 42.72 | 43.32 | 43.46 |
| Water..... | 34.57 | .... | .... | .... |

This is less basic than the previous compound. As the alcohol left is decidedly acid, it must contain either free acid or an acid sulphate.

It did not seem to be necessary to prepare other chromium sulphates, as these experiments were in accord with those obtained with the alum, and lack of time made it necessary to bring the experiments to an end.

CONCLUSIONS.

On weighing the experimental evidence which has been brought to bear upon these changes, it is an easy matter to exclude some of the explanations offered. Thus the dissociation of the alum into chromium and potassium sulphates and similar theories which will not cover the cases of the nitrates, chlorides, etc., must of course be dropped. The formation of chromo-sulphuric acid, as suggested by Recoura, is not tenable in the light of the experiments performed. The theory of the change of hydration is not satisfactory, since it has been seen that a loss of one-half the water did not bring about the change of color.

The theory of Berzelius, however of the formation of basic salts of chromium which would naturally be green and uncrystallizable, offers a full and sufficient explanation of the changes, and is in accord with the observations so far as they have been verified by us. It accounts quite plausibly for the partial withholding of the sulphuric acid from precipitation by barium chloride in the cold, and is strongly confirmed by the experiments with alcohol. This theory is also in accord with the facts that

the green coloration may be brought about by the addition of alkaline substances, and that it is retarded by the addition of sulphuric or nitric acid. It is also easy to apply this explanation to the cases of the nitrate, chloride, acetate, and soluble compounds of chromium. When we have opportunity we propose examining the action of alcohol upon these other compounds.

NESTING HABITS OF SOME SOUTHERN FORMS OF BIRDS IN EASTERN NORTH CAROLINA.

T. GILBERT PEARSON.

The coastal region of North Carolina, especially south of Hatteras, having its temperature moderated by warmer ocean currents affords many interesting forms of life both in the fauna and flora whose natural habitat would naturally be looked for at a much more southern point. Thus the palmetto (*Sabal palmetto*) which grows wild to a height of 30 feet on Smith's Island is also found in a more stunted form as far north as the banks of Cape Hatteras. This northward extension of the habitat of some Southern birds is somewhat in keeping with that of the flora.

While spending some time in eastern North Carolina during the past summer I observed there some species of southern birds which have hitherto been overlooked by ornithologists as occurring within the limits of this State; and my purpose in publishing the following notes is to record such of these observations as may be of interest.

Worthington's Marsh Wren.¹ (*Cistothorus palustris griseus*).

The range of this bird as given by Mr. Brewster¹ and later by Frank M. Chapman in his "Handbook of Birds of Eastern North America" is the "Coast of South Carolina and Georgia." In the marsh on Gull Island in Pamlico sound about twenty miles north of Cape Hatteras marsh wrens were found in great numbers on May 20th. The island which is approximately two hundred acres in extent is little more than a continuous salt marsh over the greater part of which the water rises at high storm tides. At the time of my visit the birds were in full song and from every side of the marsh came the notes of scores of birds. While singing the performers usually occupied positions entirely out of sight except as occasionally they would make short flights upward and burst into song as they dropped back again into the cover of the high thick grass.

It was evidently too early in the season for the birds to be breeding for, of the twelve nests found and examined, there were none that contained either eggs or young. The nests were suspended among the grass stalks at distances varying from sixteen to twenty inches above the ground or shallow waters. They were entirely roofed over and varied in form from almost round to elliptical. They were composed of the dead stems and blades of marsh grass neatly wound and woven together while the material was yet damp, thus forming a strong and very durable structure. The entrance was a small opening in

¹This new variety was described by William Brewster in the Auk for July 1893, Vol. 10, pp. 215-219.

It differs from the species *C. palustris* mainly in having the black of the upper parts duller and less extended, brown of the sides, flanks and upper parts much paler and grayish, and the dark markings of the under parts confused and inconspicuous.

the side near the top of the nest.¹

A specimen taken at this time was identified by Mr. C. S. Brimley, of Raleigh, N. C. as being a Worthington's Marsh Wren.

On June the 9th I heard wrens singing in the marshes near Southport which I took to be of this species but as no specimens were secured I shall not claim this as a record.

During July and the early part of August wrens were frequently heard in the salt marshes about Beaufort harbor. A visit to some of the marshes on August the 2nd resulted in the finding of a few empty nests and securing after much labor a single specimen. Wishing to be certain as to the identification of this the skin was sent to Prof. Ridgway of the Smithsonian Institution who identified it as being a fair type of *C. p. griseus*.

This race will probably be found subsequently to be a common summer resident in suitable localities along the entire North Carolina coast.

Florida Cormorant, (*Phalacrocorax piliphus florida-mus*). While Florida is the typical home of these Cormorants it has long been known that in the summer they occur along the Atlantic coast as far north as North Carolina. They have not been recorded as breeding in this State; however, as far as I have been able to learn.

Following the course suggested by numerous rumors, I penetrated the forests and swamps of Craven Co. for a distance of about eighteen miles south of Newbern and found on the 25th. of May, a colony of these birds breeding around the shores of Big Lake. The nests were located on the spreading branches of stunted cypress

¹ A typical nest shows the following external measurements, length from bottom to top 5, in. Depth, 4.25 in. Width, 3.75 in. Entrance to nest, 0.85 in. by 1.12 in. The wall of the nest varies from 0.25 to 0.50 inch.

trees standing in the water from fifty to two hundred yards from the shore. Eighteen trees were thus occupied, the number of nests each tree bore varying from one to twelve. In one tree however there were thirty-eight occupied nests.

The colony was scattered along the lake side for a distance of a mile and a half. The eggs or young contained in each nest varied from two or four in number. In color the eggs are a pale bluish white overlaid with a more or less soft calcareous coating, and measure about two and a half inches in length by one and a half in width.¹

The young birds were covered with black down, many of them being large enough to leave their nests and climb about on the branches of the trees. In doing this they would often lose their balance on the limbs while endeavoring to escape, but instead of falling into the water the hook at the point of the long bill would invariably catch on the perch and by dint of much scratching the birds would soon regain their former position. So well could they use their bills for climbing that Mr. H. H. Brimley of Raleigh N. C. to whom some of these were sent remarked afterwards in a letter that they repeatedly climbed with apparent ease up the wire netting which composed the sides of their cage.

The food of the cormorants at this season of the year must consist largely of eels, (*Anquilla anquilla*). In

¹ The exact measurements in inches and hundredths of two sets of eggs selected at random are here given: A set of four eggs measured 2.50x1.56; 2.53x1.62; 2.47x1.53 and 2.50x1.56. A set of three showed somewhat smaller dimensions, 2.32x1.56; 2.32x1.32 and 2.24x1.53, the average for the seven specimens being 2.42x1.55. Chapman makes no distinction in measurements between the eggs of this variety and the species from which it is derived, giving the measurements of the latter as 2.40x1.40. It is quite possible however that measurements taken from a much larger series of eggs of the Carolina bird might show quite a different result from the above.

nearly every nest signs of eels remains were seen, the young birds upon becoming excited would disgorge fragments of eels. The old birds which were taken usually had the slime of eels about their heads, necks and bills.

The trees, which contained each a number of nests, were completely covered, trunk, limbs, twigs, and nests, with a white coating caused by the fishy excrement of the birds. So white and marked an aspect did the trees present that although they were not usually over twelve or fifteen feet in height their outline could clearly be made out against the dark background of the cypress swamp as we passed in our canoe along the south side of the lake five miles away.

On Jones' mill pond near Newport, Carteret Co., cormorants were commonly reported to breed, but a search of the region failed to reveal any colony. This location is nevertheless evidently a popular roosting resort. A little before sundown on the day I visited it cormorants began to come in over the swamp and in a short time two or three hundred individuals had gathered in the cypress trees along the shores of the pond.

Anhinga, Water Turkey, (*Anhinga anhinga*). This is another bird which we may now add to the list of the *avifauna* of North Carolina. It is a bird of a tropical and subtropical America and has been known to breed as far north as South Carolina.

In damming up a stream on the Orton rice-plantation in Brunswick Co. fifteen miles below Wilmington, a pond was formed which extends back into the woods among the higher ridges for several miles. At the upper end of one of these narrow tongues of water is located a colony of some four or five hundred pairs of herons, which each year assemble to breed in the cypress trees.

While approaching this heronry on the 7th of June an anhinga was flushed from its nest in a small cypress tree about ten feet above the water. It flew rapidly

away but soon returned and was secured a few minutes later upon alighting near the nest. It proved to be a male in magnificent plumage. One other bird, also a male, was seen in the neighborhood but no other nests were noticed. The nest examined was a heavy structure of sticks and twigs lined with long gray moss (*Tillandsia usneoids*). It contained four eggs well advanced in incubation. In appearance they very much resembled the eggs of the cormorant but are smaller, an average egg measuring 1.15×1.35 .¹ In the neighborhood of Lake Wacamaw and the region south and east of there I occasionally heard mention of this bird from the inhabitants and do not doubt but that in suitable localities throughout the south-eastern part of North Carolina the Anhinga is a frequent summer resident.

¹ Chapman's Handbook of Birds of Eastern North America, 1897, p. 93.

THE DICHOTOMOUS GROUP OF *Panicum* IN THE EASTERN UNITED STATES.

1) CONTRIBUTION FROM MY HERBARIUM. NO. III.

W. W. ASHE.

The dichotomous section of *Panicum* presents a great difficulty to satisfactory segregation in the confusing and often nearly similar forms acquired not only by nearly related, but even quite dissimilar species in the later, branched condition which the simple primary culm generally assumes after the expansion of its panicle, and sometimes even preceding its expansion. The following descriptions are based on the character of the simple

¹ Issued Nov. 10th, 1898.

state and until one is familiar with the summer and autumnal forms assumed by different types in the group the simple state is necessary in order to make a satisfactory determination. Habit, also, is a character of great value in making determinations in this group, with specimens in either the simple or branched states; and habit should always be noted when specimens are secured. The leaves on the branches are much smaller than the primary leaves, the panicles are much smaller, and the spikelets are generally smaller and more acute. The limitations of the species are, in practically all cases, sharply defined and there are no intergradient forms.

Several of the species proposed by Lamarck, Michaux, Muhlenburg and Elliott are yet subjects of dispute or even speculation, being represented by no type specimens, while the descriptions are not sufficiently minute for accurate determination. I have been able to examine the material in the Herbarium of the Philadelphia Academy of Natural Science, which contains many specimens of Nuttall, Schweinitz, Muhlenburg, and Baldwin. The specimens of Muhlenburg and Baldwin are of particular interest; those of Muhlenburg sometimes representing his own species; while Baldwin's often indicate Elliott's, since he furnished Elliott with many specimens from Georgia. I have, besides, been able to do considerable field work in the region from which Elliott derived his material, central and southern Georgia and eastern Carolina, and have there studied the species with the view of identifying some of Elliott's species. I have found nothing so far, however, which agrees with the description of his *Panicum ovale*, *P. pauciflorum* or *P. strigosum*.

The group of the genus that I have designated as the dichotomous group is best developed, so far as number of species is concerned, in the south Atlantic States, probably in eastern South Carolina, or eastern Georgia, where the number of known species will probably amount

to thirty. This paper is only intended to cover the region between northern Florida and Indian Territory, and Minnesota and Maine. The dichotomous group can be characterized as follows:

Basal leaves different from those of the stem, broader, and generally shorter (except in a few species); spikelets all pedicelled, not racemose on the branches, neither gibbous at base, awned, or warty. Stems erect, prostrate, or decumbent, at first simple, later (except in a few species) dichotomously or fasciculately branched, producing on the branches smaller leaves and smaller panicles.

In the following paper seventy-four species are enumerated, but the real number is probably even in excess of this.

KEY TO THE EASTERN DICHOTOMOUS SPECIES OF PANICUM.

(' = one inch. " = one twelfth of an inch. = one foot.)

Leaves lanceolate or ovate-lanceolate, clasping by a broadly cordate base spikelets $1\frac{1}{4}$ " long or more; ligule a mere margin.

Largest leaves about 1' wide, panicle spreading.

Spikelets obovate, over $1\frac{1}{2}$ " long.

Nodes barbed 1. *P. Porterianum*.

Nodes glabrous 2. *P. macrocarpon*.

Spikelets elliptical, $1\frac{1}{4}$ " long

Leaves ovate-lanceolate, 2'—3' long, ciliate, sheaths soft-pubescent 3. *P. commelinaefolium*.

Leaves lanceolate, 3' long or more, sheaths papillose-hispid 4. *P. clandestinum*.

Largest leaves narrower, 5"—8" wide, ligule none.

Spikelets $1\frac{1}{4}$ " long.

Stems erect, sheaths clasping 5. *P. commutatum*.

Stems decumbent or ascending, sheaths loose 6. *P. Joorii*.

Spikelets $1\frac{3}{4}$ " long, elliptical, plant decumbent 7. *P. Manatense*.

Leaves rounded at base, lanceolate or narrower, 4"—8" wide, spikelets over $1\frac{1}{4}$ " long.

Branches of panicle erect, leaves glabrous, ligule none.

Sheaths sparingly papillose-hispid 8. *P. xanthophysum*.

Sheaths glabrous 9. *P. calliphyllum*.

Branches of panicle spreading, ligule pilose.

Panicle 3'—5' long, spikelets elliptical, numerous 10. *P. scabriusculum*.

Panicle 2'—3' long, branches and obovate spikelets few, leaves pubescent 11. *P. scoparium*.

Leaves narrower, 3"—5" wide, somewhat rounded at the base, spikelets $1\frac{1}{4}$ "—2" long.

Ligule pilose.

Nodes barbed 12. *P. malacophyllum*.

Nodes not barbed, sheaths pubescent.

Branches of panicle erect or ascending, leaves spreading 13. *P. malacon.*

Branches of panicle ascending, leaves erect 14. *P. Liebergii.*

Branches of panicle spreading ... 15. *P. Scribnerianum.*

Ligule, nodes and sheaths glabrous.

Spikelets elliptical, $1\frac{1}{2}$ " long, leaves 3'—5' long 16. *P. equilaterale.*

Spikelets $1\frac{1}{4}$ " long, leaves about 2' long.

Leaves spreading, stem nearly naked below 17. *P. Ashei.*

Leaves ascending, stem leafy below 18. *P. Webberianum.*

Leaves erect, 2"—3" wide, somewhat rounded at the base, pubescent, at least the lower ones, spikelets broadly elliptical, $1\frac{1}{4}$ "— $1\frac{1}{2}$ " long.

Stem erect, strict, leaves not crowded (western) 19. *P. Wilcoxianum.*

Stems much branched from the base, diffuse (southern) 20. *P. Georgianum.*

Leaves 3"—10" wide, lanceolate, erect or ascending, clasping by a cordate, ciliate base: lower sheaths overlapping, longer than the internodes; spikelets small, $\frac{7}{8}$ " long or less, nearly spherical, numerous.

Leaves 6"—10" wide, ascending 21. *P. polyanthes.*

Leaves 4"—6" wide.

Leaves ascending, spikelets $\frac{7}{8}$ " long .. 22. *P. sphaerocarpon.*

Leaves erect: spikelets scarcely $\frac{1}{2}$ " long 23. *P. erectifolium.*

Leaves scattered on the stem, linear-lanceolate or longer, erect, 1"—5" wide, all except the lowest narrowed to the base; branches of panicle ascending or at length spreading; spikelets 1"— $1\frac{1}{2}$ " long, very strongly nerved, nodes not barbed.

Upper leaves not over 3" wide, middle leaves longest.

Spikelets broadly obovate.

Pubescence ascending, rigid 24. *P. Addisonii.*

Pubescence, if present, villous, spikelets nearly $1\frac{1}{4}$ " long 25. *P. consanguineum.*

Glabrous or nearly so, spikelets 1" long 26. *P. neuranthum*

Spikelets elliptical, acute 27. *P. angustifolium.*

Upper leaves 3" 5" wide, much longer than the lower 28. *P. Bicknellii.*

Low, densely tufted; leaves linear, 1"—2" wide, erect, crowded near the base of stems, upper not reduced, narrowed to the base; branches of panicle erect or ascending; spikelets broadly elliptical or obovate, 1" or more long, nodes not barbed.

Spikelets obovate, over $1\frac{1}{2}$ " long, second and third scales much longer than the fourth 29. *P. depauperatum.*

Spikelets elliptical, second, third and fourth scales equal.

Spikelets 1"—1¼" long, basal secondary panicles developed 30. *P. linearifolium*.

Spikelets barely 1" long, no basal panicles developed 31. *P. Werneri*.

Leaves narrowed to the base, lanceolate or narrower, spikelets 1¼"—1½" long, plant nearly glabrous, lower nodes barbed 32. *P. nemopantherum*.

Stems simple at length fasciculately branched erect, or sometimes prostrate, stem leaves numerous, scattered, spreading or ascending, lanceolate, 1½"—8" wide, clasping by a rounded or narrowed base, the upper generally not conspicuously reduced in size, and never elongated, the basal usually shorter than those of the stem; spikelets less than 1¼" long.

Nearly or quite glabrous species without a long hairy ligule.

Nodes not barbed, spikelets ¾"—1" long.

Plant strict, erect.

Leaves spreading, narrowed to the smooth base 33.

P. dichotomum.

Leaves ascending.

Base of leaves narrowed, rounded, ciliate, sheaths not spotted 34. *P. boreale*.

Leaves narrowed to the glabrous base, sheaths spotted 35. *P. maculatum*.

Plant rising from a geniculate base.

Leaves 3'—4' long, 36. *P. Roanokense*.

Leaves less than 1½' long 37. *P. demissum*.

Nodes barbed.

Spikelets 1" long 38. *P. Mattamusketense*.

Spikelets ¾" long 39. *P. barbulatum*.

Nodes not barbed, spikelets less than ¾" long.

Strict, not prostrate or reclining; 8'—16' high.

Leaves 1"—3" wide, with a firm, white margin 40. *P. ensifolium*.

Leaves 1" wide or less, densely tufted.

Branched only from the base ... 41. *P. Baldwinii*.

Much branched towards top of culm 42. *P. Wrightianum*.

Stems at first erect, at length elongated and reclining, spikelets obovate, ¾" long 43. *P. sphagnicolum*.

Stems prostrate, spikelets broadly elliptical ¾" long 44. *P. lucidum*.

Stems ascending or reclining, spikelets narrowly elliptical, 3-5" long 45. *P. Cuthbertii*.

Nearly or quite glabrous species with a long pilose ligule.

Spikelets ½" long or less.

Spikelets about ½" long 46. *P. parvispiculatum*.

Spikelets scarcely $\frac{1}{3}$ " long 47. *P. leucothrix*.
 Spikelets $\frac{3}{4}$ "—1" long, obovate.

Panicle oblong, its branches erect or ascending 48. *P. Eatonii*.

Panicle broadly ovate, its branches spreading.

Leaves erect, panicle $1\frac{1}{2}$ " long or less 49. *P. Columbianum*.

Leaves ascending, panicle 1"—3" long 50. *P. nitidum*.

Sheaths more or less pubescent and often stems and leaves.

Leaves 4"—8" wide, spikelets $\frac{3}{4}$ "— $1\frac{1}{4}$ " long.

Strict, 2ft.—3ft. tall, pubescence villous .. 51. *P. Huachucae*.

Stems ascending, geniculate at base.

Pubescence pilose, velvety, spikelets oval $1\frac{1}{8}$ " long 52. *P. viscidum*.

Pubescence villous, ascending, spikelets obovate, 1" long 53. *P. ciliiferum*.

Stems erect, at length decumbent, leaves appressed pubescent beneath.

Spikelets $\frac{7}{8}$ " long, leaves, ascending 54. *P. tsugetorum*.

Spikelets $\frac{3}{4}$ " long, leaves spreading 55. *P. Tennesseeense*.

Leaves 2"—4" wide, spreading or ascending, spikelets about 1" long.

Lower branches of panicle ascending, pubescence hirsute-pappilose 56. *P. Atlanticum*.

Lower branches of panicle spreading.

Strict, leaves spreading, basal leaves not prominent.

Pubescence rough, ascending, spikelets nearly spherical or broadly elliptical 57. *P. scoparioide*.

Pubescence, villous, long, spreading spikelets elliptic 58. *P. villosissimum*.

Pubescence softer, ascending spikelets elliptic 59. *P. pubescens*.

Strict; leaves erect or ascending.

Leaves lanceolate, panicle as broad as long.

Pubescence ascending-appressed 60. *P. Commonsianum*.

Pubescence ascending or spreading 61. *P. haemacarbon*.

Leaves linear-lanceolate, panicle oblong 62. *P. arenicolum*.

Tufted, stems soon reclining, few-leaved, basal leaves very numerous and long 63. *P. laxiflorum*.

Leaves 2"—4" wide, spikelets $\frac{3}{4}$ "— $\frac{7}{8}$ " long.

Lower branches of panicle ascending 64. *P. lanuginosum*.

Lower branches of panicle wide-spreading.

Sheaths papillose-hirsute 65. *P. implicatum*.

Lower sheaths velvety, and nodes barbed 66. *P. annulum*.

Leaves less than 2' wide, erect, low species.

Panicle 1'—1½' long 67. *P. meridionale*.

Panicle less than 1' long 68. *P. filiculme*.

Stem leaves few, short, 1½' long or generally much less, distant, the densely tufted basal leaves as long as the stem leaves or nearly so, and broader; spikelets 1" long or less.

Basal leaves ciliate around the entire margin; otherwise glabrous.

Spikelets elliptic, 1" long 69. *P. ciliatum*.

Spikelets obovate, ¾" long 70. *P. polycaulon*.

Basal leaves soft pubescent as well as ciliate 71. *P. longipedunculatum*.

Margin of basal leaves not ciliate.

Stems pubescent 72. *P. microphyllum*.

Stems glabrous, ligule short, pubescent, 73. *P. Brittoni*.

Stems glabrous, ligule none 74. *P. glaberrimum*.

1) *PANICUM PORTERIANUM* Nash, Torr. Bul. 22:420 (1895). *P. latifolium* Walt. Fl. Car. 1788. Not L. (1753). *P. Walleri* Poir., (1816). Not Pursh. (1814).

Stems somewhat tufted, erect, columnar, soft-villous, or nearly glabrous, at first simple, at length somewhat branched at the top. Sheaths shorter than the internodes, or the upper ones overlapping, soft pubescent, or nearly glabrous and only the nodes barbed with soft hairs, ligule a mere margin. Primary leaves ovate-lanceolate, 2'—2½' long, ¾'—1' wide, cordate at base, abruptly acuminate, glabrous or roughish above, glabrous or soft-pubescent beneath, 6—13-nerved; secondary leaves smaller. Panicle short-peduncled, 2'—4' long, ovate, the few branches ascending or spreading; spikelets rather few, obovate, acute, nearly 2" long; pubescent.

Northern Florida and Texas to Missouri and New York.

2) *PANICUM MACROCARPON* Le Conte, Torr. Cat. 91 (1819). Stem strict, 12'—20' high, glabrous. Sheaths glabrous; ligule a mere margin. Leaves 2'—4' long, about 1' or more broad, 7—11-nerved, glabrous, except the rough, ciliate margins. Panicle 3'—4' long, the few-

flowered branches single, ascending; spikelets nearly 2 long, broadly obovate, obtuse.

Plant bright green. Maine and Ontario, to Minnesota, Missouri and North Carolina. Generally confused with *P. Porterianum*. This species has been supposed to be confined to Vermont, New York, Pennsylvania, and New Jersey. Maine: Fernald., 1897. Ontario: Biltmore Herbarium, No. 7066. Missouri: Stewart Weller, 1894. North Carolina: Ashe; Mitchell Co., July, 1893. Iowa: Hitchcock, 1889.

3) *PANICUM COMMELINAEFOLIUM* Ashe, sp. nov. Culms tufted, erect or ascending, 8'—15' high, stout, more or less pubescent. Sheaths more than half the length of the internodes, generally softly pubescent; ligule a mere margin. Leaves crowded, longer than the internodes, spreading or ascending, ovate-lanceolate, acuminate, abruptly narrowed to the cordate base, 11—15-nerved, 2'—3' long, 6"—14" wide, glabrous above, minutely pubescent beneath, the margins ciliate and serrulate. Panicle ovate, 2'—3' long, short-peduncled, branches numerous, spreading; spikelets smooth, elliptical, 1½" long, the first scale one-third the length of the 7-nerved second and third. Later forms branched above; with smaller leaves, the smaller panicles partly included in the sheaths.

A species having the foliage of *P. Porterianum*, and the spikelets of *P. commutatum*. Based on material collected by Dr. J. K. Small near Stone Mt., Ga., Aug. 1—6, 1895, and distributed as *P. commutatum*.

4) *PANICUM CLANDESTINUM* L. Sp. pl. 58 (1753). *P. pedunculatum* Torr. Fl. U. S. 141 (1824). Culms erect from a short rootstock, often covering many square feet, 16'—30' high; stem glabrous or nearly so above, papillose-hispid below. Sheaths of primary stem one-half as long as the joints or more, the lower ones papillose-hispid, the upper glabrous, the panicle long-peduncled; sheaths on the branches much crowded and overlapping, papillose-hispid, concealing the small panicles; ligule none. Largest leaves 1' broad, 3'—5' long, cordate at

base, taper-pointed, glabrous except the rough margins, 9—13-nerved, those on the branches much smaller. Panicle 3'—5' long, oval, the numerous branches spreading, many-flowered; spikelets $1\frac{1}{4}$ " long, elliptical.

Very common near the banks of streams. Related to *P. scabriusculum*. Torrey's *P. pedunculatum* represents the early form. New York: Ashe; Watkins, July, 1898. Florida: Chapman; Apalachicola. Missouri: Eggert; St. Louis, 1897. Michigan: Sartwell; Detroit, 1892. North Carolina: Ashe; Wilmington, 1894.

5) *PANICUM COMMUTATUM* Schultes, Mant. 2: 24 (1824). *P. nervosum* Ell. Sk. 1:122, Not Lam. *P. nervosum* Muhl. refers to another plant. Culms somewhat clustered, erect or ascending, often somewhat purplish, smooth and glabrous. Sheaths, short, glabrous except the villous margin; ligule a mere margin. Basal leaves lanceolate or broader, glabrous; stem leaves spreading, lax, lanceolate, scarcely narrowed at the ciliate, cordate base, $2\frac{1}{2}$ '— $3\frac{1}{2}$ ' long, 6"—3" wide, glabrous on both surfaces. Panicle variable, 1'—3' long, ovate, the branches fascicled, at length spreading; spikelets elliptical or obovate, $1\frac{1}{4}$ " long, somewhat pubescent.

Shady woods.—Very common.—Closely related to *P. Joori* and *P. Manatense*. Connecticut: Eames; Bridgeport, 1897. New York: Ashe; Ithaca, 1898. Missouri: Stewart Weller, 1894. Florida: Curtiss, 1894, No. 4636.

6) *PANICUM JOORI* Vasey, Contrib. U. S. Nat. Herb. III, 1:31 (1891). Culms tufted, ascending or prostrate, much branched from the base upwards, 8'—19' long. Sheaths loose, often as long as the internodes, glabrous except the ciliate margins; ligule a mere margin. Leaves very numerous, lanceolate or broader, taper-pointed, narrowed to the cordate, sparingly ciliate base, otherwise glabrous, 7—9-nerved; later leaves much smaller. Panicle small, 1'—2' long, nearly sessile or partly included in the upper sheath, oblong; spikelets very long pedicelled, $1\frac{1}{4}$ " long, elliptical, acute, glabrous.

Closely related to *P. commutatum*, and *P. Manatense*. Missouri.

Tennessee and southward. Missouri: Bush, July, 1895, No. 748.
 Tennessee: Biltmore Herbarium; Rutherford Co. No. 2984a.
 Louisiana: Joor. Mississippi: Tracy, 1891.

7) *PANICUM MANATENSE* Nash, Torr. Bul. 24 42 (1897). Stems tufted, glabrous, ascending or decumbent, soon much branched above. Lower sheaths shorter than the internodes, loose; upper crowded; ligule a mere margin. Leaves lanceolate 2'—3½' long, 5"—7" wide, taper-pointed, cordate at the ciliate base. Primary panicle long-peduncled, 2'—3' long, broadly ovate, spikelets acute, elliptical, about 1¼" long, first scale one-third the length of the 7—9-nerved second and third. Whole plant dark green in color.

With the foliage and general appearance of *P. commutatum* it is distinguished from it by having larger acute spikelets, and a decumbent habit. Florida: Nash; Manatee Co., 1895, No. 2428a.

8) *PANICUM XANTHOPHYSUM* A. Gray, Ann. Lyc. N. Y. 3: 233(1835). Culms generally single, erect, unbranched, forming no late, fascicled branches. Sheaths with a few ascending, stiff, papillose hairs; ligule a mere margin. Leaves ascending, or erect, glabrous, 4'—6' long, 5"—7" wide, lanceolate, narrowed to the rounded base, 5—7-nerved. Panicle long-peduncled, very narrow, the few, single branches appressed; spikelets very few, short-pedicelled, 1½" long, obovate, first scale nearly one half as long as the 7—9-nerved second and third.

Plant light green, resembling *P. calliphyllum* in color and habit. Maine to Manitoba, south to Pennsylvania. Description based on material collected by the writer in central New York, July, 1898; and the material in the Gray-Herbarum; and from Maine: Merrill, 1897.

9) *PANICUM CALLIPHYLLUM* Ashe, sp. nov. Stems single or few together, erect, remaining entirely simple, glabrous. Sheaths shorter than the internodes, glabrous except the ciliate margin. Leaves ascending, 3'—4' long, 4"—6" wide, lanceolate, taper-pointed, narrowed to the rounded, ciliate base, otherwise glabrous, 7—9-nerved; basal leaves few and small. Panicle sessile or short-pe-

duncled, 2'—3' long, the few-flowered branches ascending; Spikelets $1\frac{1}{2}$ " to $1\frac{1}{4}$ " long, obovate, the slender pedicels two to many times their length.

Dry soil, central New York. Plant light green, drying yellowish. Closely resembling *P. xanthophysum* to which it is related. Type material collected by the writer at Watkins, Lake Seneca, N. Y., Aug. 1898. It has also been collected by Prof. W. W. Rowlee: East Schroepel, N. Y., June 1895.

10) *PANICUM SCABRIUSCULUM* Elliott, Sk. 1:121(1817). *P. Nealleyi* Vasey. Culms forming large tufts, erect, 2-4 feet high, at first simple, at length much branched at each joint; stem glabrous. Lower sheaths generally spotted with purple, often papillose-hirsute or villous, the upper sheaths of the primary stem glabrous and distant; secondary sheaths papillose-hirsute and overlapping; ligule pilose; nodes sometimes barbed. Leaves ascending, linear-lanceolate, about 6" wide, 4'—7' long, the numerous branches ascending or spreading; spikelets very numerous, 1"— $1\frac{1}{4}$ " long, elliptical-ovate or ovate, acute, glabrous; secondary panicles concealed within the sheaths.

The affinity of this species is with *P. clandestinum*. Ditches and sunny swamps, southeastern Virginia to Texas. Not common. Virginia: Ashe; Norfolk, 1897. North Carolina: Ashe; Moore Co. 1897. Texas: Nealley, 1892.

11) *PANICUM SCOPARIUM* Lam. Encl. 7: 744(1797). Culms single or a few together, erect, strict, columnar, often purplish, papillose-hirsute. Sheaths papillose-pubescent, the pubescence harsh, the upper overlapping; ligule pilose. Lower leaves distant, the upper approximate, 2'—4' long, 5"—7" wide, firm, spreading, smooth above, beneath soft-pubescent. Panicle 2'—3' long, the few branches solitary, at length spreading, 1—4-flowered.

The affinity of this species is with *P. Scribnerianum*. Virginia: Small and Heller; Danville, June, 1892. North Carolina: Ashe; Chapel Hill, 1897. South Carolina: Ravenel; Aiken.

12) *PANICUM MALACOPHYLLUM* Nash, Torr. Bul. 24: 198, (1897). Stems somewhat tufted, erect, simple, at length much branched: sheaths rather loose, papillose-hirsute with spreading hairs; ligule a ring of short hairs; nodes barbed. Leaves narrowly lanceolate, acuminate, narrowed to the rounded base, soft-pubescent, the largest about 3' long, and 5" wide, 7-nerved. Panicle nearly sessile the branches flexuous, spreading, bearing a few short-pedicelled spikelets: spikelets about 1½" long, obovate, acute, the first scale over one third as long as the very pubescent 9-nerved second and third.

Related to *P. Scribnerianum* from which it is separated by its soft pubescence, somewhat smaller spikelets, and more slender habit.—Middle Tennessee to Indian Territory.—Indian Territory: Bush; Sappulpa, May 1895. No. 1228.

13) *PANICUM MALACON* Nash, Torr. Bul. 24: 197 (1897). Stems very slender, tufted, erect, columnar, smoothish, 16'—24' high. Sheaths much shorter than the internodes, the lower smooth, the upper papillose-hispid with ascending hairs; ligule pilose. Leaves distant, spreading or ascending, rigid, glabrous or somewhat ciliate at the base, shorter than the internodes, oblong lanceolate, acuminate, narrowed or somewhat rounded at the base, 2½'—4' long, 3"—4" wide, 7-nerved. Panicle sometimes much exserted, 2'—3' long, the slender, scattered, few-flowered branches erect or ascending. Pedicels two to many times the length of the spikelets; spikelets glabrous, broadly obovate, acutish, 1½"—2" long, the first scale 1-nerved, one-third the length of the 9-nerved second and third. Later stages somewhat fasciculately branched above, the leaves a little smaller, than the primary ones and panicles barely exserted.

Dry soil Florida. Related to *P. scoparium*. Florida: Curtiss; Jacksonville, Apr. 1897. No. 5864.

14) *PANICUM LIEBERGHII* Vasey Scribn. Bul. U. S.

Div. Bot. 8: 32 (1889). *P. scoparium* Lam. var. *Liebergii* Vasey, l. c. Culms single or few together, erect, 1—2 feet high, at first simple, at length much branched above, more or less pubescent with spreading hairs. Sheaths papillose-hirsute, the hairs spreading; ligule hairy. Leaves lanceolate, the largest 3'—4' long, 4''—5'' wide, rounded at the base, erect, papillose-hispid beneath, above generally glabrous. Panicle narrow, about 3' long, the flexuous branches erect or ascending. Spikelets obovate $1\frac{3}{4}$ '' long, the first scale nearly one-half as long as the pubescent second and third.

Very closely related to *P. Scribnerianum*. Dry soil. According to Britton and Brown extending from Minnesota and South Dakota to Nebraska, Missouri and Ohio. Iowa: Pammell, 1896.

15) *PANICUM SCRIBNERIANUM* Nash, Torr. Bul. 22: 421 (1895). *P. scoparium* var. *minor* Scribn. (1894). Not *P. capillare* var. *minus* Muhl. *P. pauciflorum* A. Gray (1848). Not Ell. (1817). *P. scoparium* Watson Sixth Ed. Gr. Man. 632 (1889). Not Lam. Encl. 4:743 (1797). Culms 8'—20' high, tufted, erect, at first columnar, at length much branched above. Sheaths shorter than the internodes, from nearly glabrous, especially in the northern forms, to papillose-hispid, the pubescence ascending; nodes not barbed. Leaves spreading or ascending, lanceolate, 2'—3½' long, 3''—5'' wide, rounded at the base, smooth above, glabrous or rough beneath. Panicle 2'—3' long, broadly oval, branches rather many-flowered; spikelets obovate, $1\frac{1}{2}$ '' long.

Most closely related to *P. Liebergii*, and *P. scoparium*, and *P. malacophyllum*. Dry soil, North Carolina and Tennessee to Wyoming, east to Ontario and Maine. North Carolina: Ashe; Raleigh, July, 1895. Tennessee: Ruth; Knoxville; 1897. Missouri: Bush; 1894, No. 729. Wyoming: Nelson; 1894, No. 516.

16) *PANICUM EQUILATERALE* Scribn. Bul. 11, U. S. Div. of Agrost. 42 (1898). Stems somewhat tufted from a generally geniculate base, glabrous. Sheaths short and

glabrous; ligule a mere margin. Leaves 4'—6' long, 3''—4'' wide, oblong-lanceolate, glabrous, abruptly acuminate. Panicle 2'—3' long, oval, branches spreading, rather many-flowered; spikelets elliptical to obovate, $1\frac{1}{2}$ ' long; first scale acute, fully one-half as long as the pubescent 9-nerved second and third, fourth scale acute.

Related to *P. Ashei*, but the leaves are much longer than those of that plant, while the spikelets are as long as in *P. Porterianum*. Florida: Baldwin; Fort George. Florida: Nash; Eustis, 1894, Nos. 1220 and 1674.

17) *PANICUM ASHEI*, Gilbert Pearson, sp. nov. *P. commutatum* Schultes var. *minor* Vasey, Contrib. from U. S. Nat. Herb., vol. 3, No. I: 32 (1892). Not *P. capillare* var. *minus* Muhl. (1817). Culm erect, strict, single or a few together from a short root-stock, very slender, glabrous, 11'—18' high. Sheaths glabrous, the lower very short; ligule none. Stem leaves rigid, spreading, lanceolate, $1\frac{1}{2}$ '—3' long, 3''—4'' wide, taper-pointed, scarcely narrowed at the ciliate base, glabrous on both sides, the lowest distant, the upper approximate. Panicle 2' long or less, oval, the few branches spreading; spikelets $1\frac{1}{4}$ ' long, elliptic, nearly glabrous. The autumnal form is sparingly branched above.

Common.—This species is closely related to *P. commutatum* from which it is separated by its slender, strict habit, more narrow, rigid and spreading leaves approximate at the top of the culm. Dry shady woods, New York to Georgia and Missouri. New York: Ashe; Ithaca, July 1898. North Carolina: Ashe; near Wilmington, June 1898. Missouri: Bush; Aug. 12, 1892, sub. nom. *P. dichotomum*, L.

18) *PANICUM WEBBERIANUM* Nash, Torr. Bul. 23: 149 (1896). Stems tufted, erect or ascending, 18'—24' high, smooth except below, where minutely puberulent. Sheaths smooth, except the ciliate margin, or sometimes puberulent, inflated, shorter than the internodes; ligule a mere ciliate margin. Leaves erect or ascending, lanceolate, narrowed to a rounded base, 2'—3' long, 3''—4'' wide, 7—11-nerved, glabrous or the base, sparingly cili-

ate, generally purplish, very numerous. Panicle 2'—4' long, one half as wide, the slender, mostly single branches spreading; spikelets obovate, apiculate, $1\frac{1}{4}$ " long, on pedicels of about the same length or longer, first scale obtuse, about one-fourth the length of the 7-nerved second and third.

Low pine land. Florida: Nash; Lake Co., May, 1894, No. 781. Related to *P. demissum* Trin. but larger in every way and erect, whereas that is ascending from a geniculate base or is prostrate.

19) *PANICUM WILCOXIANUM* Vasey, Bul. U. S. Div. of Bot. 8: 32 (1889). Culms somewhat tufted, erect, about 8' high, pubescent, at least below. Sheaths shorter than the internodes, papillose-pubescent with rough, appressed or ascending hairs; ligule pilose. Leaves in the simple form not crowded, ascending, nearly lanceolate, the largest about 3' long, 2" wide, narrowed to the somewhat rounded base, pubescent. Panicle long-peduncled, 1'— $1\frac{1}{2}$ ' long, ovoid, compact, the branches ascending; spikelets broadly elliptical, $1\frac{1}{4}$ " long, pubescent.

Dry, sandy soil, Nebraska. Type material collected by Dr. Wilcox in 1891. Closely related to *P. Scribnerianum*.

20) *PANICUM GEORGIANUM* Ashe, sp. nov. Low, 4'—8' high, densely tufted, much branched below and spreading, even before flowering; stems glabrous or soft-pubescent. Sheaths generally longer than the internodes, soft-pubescent or nearly glabrous; ligule with a few soft hairs. Leaves ascending, oblong lanceolate, 1'—2' long, about 2" wide, taper-pointed, rounded at the base, 5—7-nerved, soft-pubescent or glabrate. Panicle short-peduncled, one inch long or less, generally overtopped by the upper leaves, the few, short branches ascending; spikelets, $1\frac{1}{4}$ " long, broadly elliptical, the first scale obtuse, one-third the length of the very pubescent second and third.

Dry sandy soil, southern Georgia and Florida. Related to *P. consanguineum*. Georgia: Small; Darden Junction, McIntosh Co., June 27, 1895. Florida: Chapman; Apalachicola.

21) *PANICUM POLYANTHES* Schultes, Mant. 2:257 (1824). *P. multiflorum* Ell. Sk. 1:122 (1817). Not Poir (1816). *P. microcarpon* Muhl. Gram. 111 (June 1817.) Not Muhl. ex Elliott (Jan. 1817). Culms often single, erect or nearly so, 16'—30' high, glabrous. Sheaths glabrous, generally longer than the internodes and overlapping; ligule none. Leaves ascending, scattered along the entire stem, lanceolate, 3'—6' long, 6"—10" wide, taper-pointed, glabrous except at the ciliate, cordate base; basal leaves rosulate, ovate-lanceolate, rigid. Panicle oblong or elliptical, pointed, 3'—5' long, branches fasciculate, the lower ascending. Spikelets very numerous, nearly $\frac{3}{4}$ " long, broadly elliptical or spheroid; first scale small, one-fourth the length of the pubescent 7-nerved second and third.

Moist, shady woods, not common, Florida, Texas and Indian Territory northward to Michigan and Pennsylvania. Pennsylvania: C E. Smith, Chester. Missouri: Stewart Weller, 1892. Georgia: Ashe; Albany, 1896. District of Columbia: Holm; 1896.

22) *PANICUM SPHAEROCARPON* Ell. Sk. 1: 125 (1817). Stems sometimes tufted, erect or ascending 12'—28' long, glabrous. Sheaths glabrous (or sometimes the lower nodes slightly barbed), the lower longer than the internodes and overlapping; ligule none. Leaves ascending, lanceolate, 2'—2 $\frac{1}{2}$ ' long, 4"—5" wide, long taper-pointed, ciliate at the barely rounded base, about 7-nerved. Panicle long-peduncled, oval 2'—3' long, the fascicled branches somewhat ascending; spikelets obovate or nearly spherical, $\frac{7}{8}$ " long.

Common in old fields and sunny woods, New England and Ontario to Missouri, Mexico (fide Vasey) and Florida. New York: Townsend; Niagara, 1894. Missouri: Bush; Montier, 1894, No. 763. Georgia: Small; Stone Mt. 1895. Illinois: Hill; Chicago, 1898.

23) *PANICUM ERECTIFOLIUM* Nash, Tor. Bul. 23: 148 (1897). *P. spaeocarpon* var. *Floridanum* Vasey, Bul. U. S. Div. of Bot. 8:33 (1889). Not *P. Floridanum*

Trin. (1834) *P. spacrocarpon* Ell. ex Chapm. Flora. First Ed. 576. Culms tufted, erect or ascending, 14'—24' high, rather stout, glabrous. Sheaths glabrous, lower generally longer than the internodes; no ligule. Leaves thick, erect, rigid, lanceolate or narrower, 2'—3' long, 4'—6'' wide, taper-pointed, rounded at the ciliate base, otherwise glabrous. Panicle 1½'—3' long, oval or oblong, branches fascicled, the lower ascending. Spikelets numerous, very small, scarcely ½'' long, spherical.

Distinguished from *P. spacrocarpon* by having narrower, erect leaves, and smaller spikelets. Northern Florida and probably the adjacent parts of Georgia. Florida: Curtiss; Jacksonville, 1894, No. 4812.

24) *PANICUM ADDISONII* Nash, Torr. Bul. 25: 83 (1898). Tufted, stems erect or ascending from a geniculate base, rigid. At first simple, at length much branched, the branches erect, the lower part of the stem pubescent with long ascending hairs which become much shorter towards the top. Sheaths appressed pubescent, sometimes longer than the internodes. Leaves erect, glabrous, acuminate, lanceolate, 1'—3' long, 1½''—3'' wide; ligule pilose. Panicle, long-peduncled, ovate to oblong, the rather few branches erect or ascending; spikelets obovate, 1'' long, the first scale about one half as long as the 9—11-nerved, very pubescent second and third.

Type material from southern New Jersey. Related to *P. consanguineum*. I have found the same species in eastern North Carolina.

25) *PANICUM CONSANGUINEUM* Kth. Enum. Pl. 1: 106 (1833). Stems sometimes tufted, generally single, villous with soft spreading or ascending hairs, at least below, 12'—30' long, spreading or ascending from a geniculate base, at first simple, the autumnal form very much branched above, and often reclining. Sheaths shorter than the internodes, villous with soft grayish pubescence, ligule a ring of very short hairs, sometimes of longer.

Stem leaves erect, oblong-lanceolate, the largest near the middle of the stem, 2'—3½' long, 2"—4" wide, about equalling the internodes, thickish, smooth to villous; the later leaves smooth and much smaller, densely fascicled at the upper part of the stem. Panicle long-peduncled, 2'—3' long, the few long, flexuous branches ascending, few-flowered. Spikelets 1¼" long, broadly obovate, obtuse, abruptly contracted at the base, the second and third scales strongly 7—9-nerved, very pubescent.

Virginia: Ashe; June, 1897. North Carolina: Ashe; Chapel Hill, 1896. Florida: Curtiss. *P. oligosanthos* Schult. and *P. Rufinesquianum* Schult. are probably referable to this species.

26) *PANICUM NEURANTHUM* Griseb. Cat. Pl. Cub. 532 (1866). Culms somewhat clustered, at first simple, erect or ascending, 8'—20' long, at length very much branched above and reclining or spreading, glabrous or somewhat pubescent. Sheaths shorter than the internodes, the lower pubescent, the upper smooth, those of the fascicled secondary branches much crowded; ligule pubescent. Earlier leaves erect, flat, glabrous, linear-lanceolate, the largest 3'—4' long, 2"—2½" wide, narrowed at the base, longer than the internodes; the later crowded, smaller, linear, ascending on the spreading or reclining branches, often involute, very much longer than the small, barely exerted panicles. Primary panicle oblong, 3'—4' long, glabrous, the branches at first ascending, at length spreading, the rather few large flowers borne mostly on long flexuous pedicels; spikelets about 1" long, broadly obovate.

Dry sandy soil along the Atlantic and Gulf coasts from Virginia southward. This species is apparently very close to *P. consanguineum*. I have only been able to examine Curtiss' 3587,* which has been referred by Nash to this species, and this being in the autumnal state, is rather unsatisfactory for comparison.

27) *PANICUM ANGUSTIFOLIUM* Ell., Sk. 1:129 (1817). *P. setaceum* Muhl. Gram. (1817). Stems generally sin-

gle, at first simple and erect, later much branched, spreading or reclining, glabrous, or below somewhat pubescent. Sheaths shorter than the internodes, the lowest generally pubescent, the upper smooth. Primary leaves erect, flat, glabrous, linear-lanceolate, the largest 3'—4' long, 2'—2½" wide, narrowed at the base, secondary leaves much smaller and crowded at the top of the ascending or reclining branches. Primary panicle oblong, 3'—4' long, glabrous, the branches at first erect, at length spreading, the flowers on long flexuous pedicels, spikelets 1" long, or over, elliptic, acute, abruptly contracted at the base.

Dry sandy soil from eastern Virginia southward to Texas. Maryland: Canby, 1894. Florida: Nash; Eustice, 1894. Mississippi: Kearney; Biloxi, 1896. Texas: Reverchon; Dallas, 1881, sub. nom. *P. neuranthum*.

28) *PANICUM BICKNELLII* Nash, Torr, Bul. 24:193 (1897). Culms tufted erect, slender, smooth above, puberulent below, a foot or more tall. Sheaths often longer than the internodes, the lower pubescent with the nodes bearded; ligule pubescent. Stem leaves linear-lanceolate, narrowed at the ciliate base, otherwise smooth, the largest 5'—8' long, 4"—5" wide, the upper ones longest. Panicle 2'—4' long, with ascending, flexuous branches; spikelets obtuse, oval or obovate, about 1½" long, second and third scales 9-nerved. Secondary panicles much smaller, on erect branches, and not basal as in *P. depauperatum*.

This species has the habit and appearance of *P. depauperatum*, from which it is separated by having much broader leaves and smaller spikelets. New York, Pennsylvania and New Jersey. Porter; Pennsylvania; Chambersburg, July, 1896.

29) *PANICUM DEPAUPERATUM* Muhl. Gram. 112 (1817). *P. strictum* Pursh Fl. (1814). Not R. Br. (1812). *P. rectum* R. & S. *P. involutum* Torr. Stems tufted, 8'—18' high erect, mostly glabrous. Upper sheaths clon-

gated, glabrous or hirsute; ligule hairy. Stem leaves erect, longest towards top of culm, 3' to 8' long, $1\frac{1}{2}$ "—2" wide, smooth or hirsute, sometimes involute; basal leaves similar to those of the stem but shorter. Panicle loose, 3'—5' long, branches erect or ascending, mostly single, flexuous, few-flowered, pedicels mostly very long; spikelets $1\frac{1}{2}$ "—2 $\frac{1}{2}$ " long, broadly elliptical or obovate, acute, the 8-nerved second and third scales much longer than the obtuse fourth.

Elliott does not seem to have known this species. Throughout the eastern United States from Maine and Florida to Texas.

Dry, sandy woods and fields. Washington, D. C.: Holm, 1895. Iowa: Bessey; Ames, 1872. Georgia: Ashe; Stone Mountain, 1896. Texas: Reverchon. New Hampshire: Eaton; Seabrook, 1898.

30) *PANICUM LINEARIFOLIUM* Scribn. Bul. 11, U. S. Div. of Agr. 42 (1898). Densely tufted, 8'—14' high, stems erect, smooth. Sheaths somewhat shorter than the internodes, usually hirsute; ligule hairy. Leaves linear-lanceolate, erect, firm, 2'—6' long, $1\frac{1}{2}$ "—2" wide, the base barely narrowed, glabrous above, or with a few long hairs, below appressed pubescent. Primary panicle open, 2'—4' long, the mostly single branches ascending, the rather few spikelets borne on pedicels two to many times their length. Spikelets elliptical, obtuse, 1" or slightly more long, very strongly 7-nerved. Secondary panicles crowded at base of the culms.

Maine and New Jersey to Minnesota and Missouri. Distinguished from *P. depauperatum* by having more slender, obtuse spikelets; while its somewhat longer, more elliptical spikelets, its pubescence and the basal panicles separate it from *P. Werneri*. Minnesota; Holzinger; June, 1888. Maine; Merrill; July, 1898. Illinois; Hall; 1862. Missouri; Bush, 1892.

31, *PANICUM WERNERI* Scribn. Brit. and Brown's Ill. Flo. 3; 501 (1898). Densely tufted, stems very slender, smooth and glabrous throughout. Sheaths smooth, ligule a mere margin. Leaves linear, erect, often overtopping the panicles, the upper leaves the longest, 3'—7'

long, 1''—2'' wide, glabrous. Panicles long-peduncled, 2'—4' long, loose, the slender flexuous, generally solitary branches ascending; spikelets about 1'' long, obovate, the first scale about one third the length of the 7-nerved second and third. Secondary basal panicles only sparingly developed.

Very close to *P. linearifolium*. Connecticut to Ohio in swamps. Connecticut: Eames; Fairfield, 1896. New York: Rowlee; Ithaca, 1892.

32) *PANICUM NEMOPANTHUM* Ashe, sp. nov. Tufted, stems erect, 14'—20' high, glabrous. Sheaths glabrous, or the lowest pubescent, the upper sometimes longer than internodes, the nodes, at least the lower ones, barbed with long hairs; ligule none. Leaves linear lanceolate, spreading or ascending, long taper-pointed, glabrous or ciliate toward the narrowed base. Panicle 3'—4' long, broader than long, the mostly single branches wide-spreading, lax and drooping, few-flowered; spikelets elliptic, acute, nearly 1½'' long, on long, flexuous pedicels, the obtuse first scale over one-third the length of the glabrous, 7-nerved second and third.

Type material collected by the writer April, 1895, in the Penitentiary woods, Raleigh, N. C. A very distinct species.

33) *PANICUM DICHOTOMUM* L. Sp. Pl. 58 (1753). *P. ramulosum* Mx. *P. nodiflorum* Lam.? Several stems together, 10' -- 24' high, erect. Sheaths, except the lowest, glabrous, lowest node occasionally barbed and its sheath pubescent. Sheaths shorter than the internodes; ligule none. Leaves spreading, lax, largest 1½'—2½' long, 3''—4'' wide, narrowed to a rounded, sparingly ciliate base, otherwise glabrous. Primary panicle 2' or more long, oval, the branches lax; spikelets 1'' long, elliptic, glabrous.

Shady woods throughout the eastern United States north of Florida and Texas. Florida: Chapman; Apalachicola. Texas: Nealley; Rock

land, 1892. New York: Rowlee; Ithaca, 1895. Maine: Fernald; 1895. This is the most common vernal species from North Carolina northward. Elliott seems to have overlooked this species. His *P. dichotomum* is either *P. demissum* or *P. arenicolum* or some closely related species, which, in habit, resembles *P. angustifolium*, as he compares his *P. dichotomum* with *P. angustifolium* in both habit and form.

PANICUM DICHOTOMUM ELATUM Vasey Contrib. from U. S. Nat. Herb. vol. 3 No. 1: 30 (1892). Stems stouter, leaves longer, 2½'—3' long, panicle very much larger than in the type, 3'—4' long and fully as wide. Maryland and southward. District of Columbia: Scribner 1894. North Carolina: Ashe; Chapel Hill, 1897.

PANICUM DICHOTOMUM VIRIDE Vasey, Contrib. from U. S. Nat. Herb. Vol. 3, No. 1: 30 (1892) is a tender, slender, few flowered form, growing in very deep shady woods. It is very common to the northward, but is less common to the south. It does not branch or only sparingly during the summer, the basal nodes and sheaths are glabrous, and it is probably specific. It approaches *P. lucidum*.

P. dichotomum has been burdened with numberless varieties by later American authors, most of these varieties being well-marked species, which were so regarded by early American botanists.

34) *PANICUM BOREALE* Nash, Torr. Bul. 22: 421 (1895). Culms generally tufted, ascending or erect, 14'—20' high, glabrous. Sheaths glabrous, except for the ciliate margin, often as long as the internodes; ligule of very short hairs. Leaves glabrous, lanceolate, or sometimes ciliate at the base, 3'—5' long ½' wide or less, taper-pointed, narrowed to the rounded base, ascending. Panicle 2'—3' long, nearly as broad, branches numerous, fascicled, very slender; spikelets 1" long, elliptic, acutish, nearly glabrous, rather numerous, on long filiform ascending or spreading pedicels. Autumnal form unbranched.

Northern New England to Minnesota, South to Pennsylvania. Related to *P. dichotomum*. Maine: Merrill; East Cerebum. New York: Ashe; Courtland, 1898.

35) *PANICUM MACULATUM* Ashe, sp. nov. Culms single, erect, glabrous, at length sparingly branched. Sheaths shorter than internodes, glabrous, spotted; ligule none. Basal leaves and nodes glabrous; stem leaves ascending, largest 3'—4' long, 4''—5'' wide, lanceolate, tapering to the rounded glabrous base, margins very rough, 5—7-nerved. Panicle 2'—3' long, nearly as broad, oval, the clustered branches lax. Spikelets $\frac{3}{4}$ '' long, obovate, acute.

Related to *P. dichotomum*, from which distinguished by the longer, ascending leaves and smaller spikelets, Spikelets about the size of those of *P. barbulaum*. Collected by the writer at Raleigh, N. C. May, 1895.

36) *PANICUM ROANOKENSE* Ashe, sp. nov. Culms somewhat tufted, 18' or more high from a geniculate base. Plant glabrous throughout. Sheaths one-half as long as the internodes or more; ligule none. Leaves glabrous, ascending, narrowly lanceolate, 2'—3' long, 2''—3'' wide, firm, 5—7-nerved. Panicle $2\frac{1}{2}$ '— $3\frac{1}{2}$ ' long, broadly oval, the slender, fascicled branches spreading or drooping; spikelets numerous, 1'' long, elliptical-obovate, glabrous.

Type material collected by writer in dry soil, Roanoke Island, N. C. June, 1898; also collected at Rose Bay and Mackleyville, N. C., the same month.

37) *PANICUM DEMISSUM* Trin. Sp. Gram. 3: 319 (1836), *Panicum Nashianum* Scrib. Bul. U. S. Div. of Agrost. 7: 79 (1897). Stems tufted, 10'—18' long, very slender, wiry, rising or reclining from geniculate base, joints geniculate, purplish, glabrous or minutely rough, puberulent below, at first simple, becoming much branched above late in the season. Sheaths much shorter than the internodes, the upper ones glabrous, the lower gen-

erally puberulent; ligule none. Leaves ascending, oblong-lanceolate, $1\frac{1}{2}$ ' long or less, about 2'' wide, 1' longest and broadest near the base of the culm, the upper reduced in size, glabrous. Panicle short-peduncled or sessile, 1'—2' long, the branches short, flexuous, spreading; spikelets obovate, 1'' long, contracted at the base, glabrous.

Related to *P. Webberianum*, but distinguished by being much smaller and ascending from a geniculate base. Common in the pine barrens. North Carolina; Ashe; near Newberne, 1898. Georgia; Small; near Thomasville, June, 1892. Florida; Curtiss; Jacksonville, No. 4637, 1894.

38) *PANICUM MATTAMUSKETENSE* Ashe, sp. nov. Erect, sometimes tufted, strict, rather stout, 2 feet to 4 feet high, often purplish, nodes strongly barbed. Lower leaves and sheaths soft-pubescent the upper glabrous; ligule pubescent, otherwise glabrous. Leaves lanceolate, 3'—5' long, 4''—7'' wide, spreading. Panicle 3'—5' long, ovoid, long-peduncled, the branches numerous, clustered; spikelets ellipsoid, glabrous, pointed, 1'' long, first scale one-third the length of the spikelet.

Roadsides, ditch banks and wet open woods around lake Mattamuskeet, N. C., where it grows with *P. barbulatorum*. June and July. The later stages profusely branched above with shorter leaves and small few-flowered panicles. Collected by the writer, and Mr. Gilbert Pearson in June, 1898.

39) *PANICUM BARBULATORUM* Mx. Flora, 1:49(1803). *P. discolor* Spreng. ex Muhl. Gram. 114(1818). *P. heterophyllum* Schreb? Stems erect, often tufted, 2 feet to 3 feet high, the nodes barbed, otherwise glabrous. Sheaths shorter than the internodes, glabrous; ligule pubescent. Leaves spreading or ascending, lanceolate, rounded at the base, 3'—4' long, 3''—6'' wide. Panicle 3'—5' long, ovoid, peduncled, the branches fascicled, numerous; spikelets ellipsoid about $\frac{3}{4}$ '' or less long, pointed. The later stage very much branched above, with smaller leaves and small, few-flowered panicles.

Wet shady places, very common. Florida and Texas to (according to Britton & Brown) Ohio and Connecticut. Texas: Nealley; No. 26. Florida: Chapman: Apalachicola. Biltmore Herbarium, No. 803c. District of Columbia: Kearney, 1895. Kentucky: Miss Price; Bowling Green. This species has the general appearance of *P. dichotomum*, but is distinguished by the smaller spikelets and barbed nodes. Nearly related to *P. annulum* and *P. Mattamusketense*.

40) *PANICUM ENSIFOLIUM* Baldwin, Ell. Sk. 1:526 (1817). *P. albo-marginatum* Nash, Torr. Bul. 24:40 (1897). Stems tufted, branching from the base or near it, glabrous, 8'—14' high. Sheaths generally much shorter than the internodes, crowded on the branches above, glabrous, except the very short, hairy ligule. Leaves glabrous, lanceolate, mostly clustered near the base of the stem, the largest $1\frac{1}{2}$ '—2' long, 3"—4" wide, the margins white and thickened, upper reduced in size. Panicles small, 1'— $1\frac{1}{2}$ ' long, long-exserted, oval, the branches ascending; spikelets numerous, $\frac{3}{4}$ " long, elliptical-obovate, the first scale about one-fourth as long as the pubescent 7-nerved second and third.

Moist or dry woods middle North Carolina to Florida. North Carolina: Ashe; Chapel Hill, June, 1896. Georgia: Baldwin. Florida: Nash; Lake county, 1894, No. 925. A specimen in the herbarium of the Philadelphia Academy of Science sent by Baldwin from Georgia, and labelled by him *P. ensifolium*, matches my material from North Carolina and Nash's from Florida. It also agrees very well with Elliott's description of this species.

41) *PANICUM BALDWINII* Nutt. ex Chapman, Flora, 3rd edition 586 (1896). Densely cespitose, glabrous, stems much branched near the base, low 8'—16' high, stiff and rigid. Sheaths smooth; ligule pubescent. Stem leaves rigid, erect, narrowed at base, $\frac{1}{2}$ '— $1\frac{1}{2}$ ' long, acuminate, glabrous. Basal leaves tufted. Panicle 1' or less long, much divided; the obovate or elliptic spikelets barely $\frac{1}{2}$ " long, the second and third scales indistinctly 5-nerved.

Georgia: Baldwin, in Herb. Philadelphia Acad. of Natural Science. Florida: Curtiss; Indian river, No. 5804. Florida: Chapman; Apalachicola. Related to the next.

42) *PANICUM WRIGHTIANUM* Scribn., Bul. 11, U. S. Div. of Agrost., 44 (1893). Stems densely tufted, much branched above, sometimes puberulent. Sheaths very short, occasionally pubescent; ligule sometimes pubescent. Leaves lanceolate, somewhat rounded at the base, 1'—2' long, erect, glabrous, taper-pointed. Panicle oblong, $\frac{1}{2}$ '—1 $\frac{1}{2}$ ' long, branches fascicled, short; spikelets obovate, less than $\frac{1}{2}$ " long, second and third scales faintly 5-nerved.

Florida and westward along the South Atlantic and Gulf coasts. Florida: Nash; Lake county, 1894, No. 1238. Florida: Curtiss; Jacksonville, 1894, No. 5588. North Carolina: Ashe; near Newberne, 1898.

43) *PANICUM SPHAGNICOLUM* Nash, Torr. Bul. 22: 422 (1895). Cespitose, stems at first erect, soon reclining and much elongated, 12'—30' long, very slender, glabrous. Sheaths much shorter than the internodes, glabrous, no ligule. Leaves erect, $\frac{1}{2}$ '—1 $\frac{1}{2}$ ' long, 2"—3' wide, narrowly lanceolate, narrowed to the somewhat rounded base, glabrous, 5-nerved. Panicles 1'—1 $\frac{1}{2}$ ' long, branches erect, or ascending; spikelets $\frac{3}{4}$ " long, broadly obovate, glabrous, the second and third scales 7-nerved.

Delaware to Florida and Tennessee. At first unbranched, eventually with slender, reclining branches and small, sessile panicles. Color light green. Delaware: Canby; Ogletton, June, 1896. District of Columbia: Kearney; June, 1897. North Carolina: Small; Duns' Mt., August, 1894. North Carolina; Biltmore Herbarium, Biltmore, August, 1898 No. 5066b. Florida; Nash, No. 2500.

44) *PANICUM LUCIDUM* Ashe, sp. nov. Cespitose, culms reclining or prostrate, weak, glabrous. Sheaths glabrous, except the ciliate margin, very short; ligule none. Leaves spreading, 1' long or generally less, narrowly lanceolate, very acute, narrowed to the base, glabrous, rather distant. Panicle peduncled, 1 $\frac{1}{2}$ ' long or less, equally as wide, the branches single or several together,

wide-spreading; spikelets about $\frac{3}{4}$ " long, elliptic or narrowly obovate, acute, glabrous.

Collected in June 1898 by the writer in deep, shady swamps bordering lake Mattamuskeet, N. C. Probably found in other swamps along the coast of the southern states. Very different from *P. sphagnicolum*.

45 *PANICUM CUTHBERTII* Ashe, sp. nov. Culms very slender, erect or spreading, densely tufted, glabrous, 8'—24' long, the autumnal state unbranched or slightly so. Sheaths very short, glabrous; no ligule. Stem leaves distant, narrowly lanceolate, taper-pointed, 3 to 5 nerved, narrowed at the base, thin, glabrous, $\frac{1}{2}$ '—1 $\frac{1}{2}$ ' long, 1"—2" wide, spreading or ascending; basal leaves densely tufted. Panicle broadly oval about 1' long, the slender branches spreading; spikelets narrowly elliptical, acute, $\frac{1}{2}$ " long, the first scale one-fourth the length of the 7-nerved finely pubescent second and third.

Wet sandy woods, North Carolina and South Carolina. South Carolina: Cuthbert; St. Helena island. North Carolina: Ashe; Chapel Hill. June, 1898. It is separated from *P. ensifolium* by the strict habit and arge basal leaves of the latter; while *P. sphagnicolum* has the branches of its panicle ascending and larger obovate spikelets; and *P. lucidum* has much larger and broader spikelets, and a decumbent habit.

46) *PANICUM PARVISPICULATUM* Nash, Torr. Bul. 24:347 (1897.) *P. microcarpon* (?) Muhl. ex Ell. Sk. 1:127 (1817). Stems tufted, erect, 8'—30' high, glabrous, or with some appressed pubescence on the lower part and sometimes with the nodes barbed. Sheaths very short, generally glabrous, the lower sometimes pubescent; ligule short, pilose. Leaves distant, ascending, much shorter than the internodes, lanceolate, narrowed at the base, 2'—3' long, 3"—4" wide, generally glabrous. Basal leaves oblong lanceolate, 2'—4' long, about $\frac{1}{4}$ " wide, stiff and erect. Panicle 1 $\frac{1}{2}$ '—3' long, oval or oblong, the numerous ascending branches thickly fascicled; spikelets very numerous, small, scarcely $\frac{1}{2}$ " long, broadly oval.

This species is intermediate between *P. leucothrix* Nash. and *P. niti-*

dum Lam., and is the *P. nitidum* of Dr. Chapman's Southern Flora. It is also probably the *P. microcarpon* of Elliott. It occurs along the coast as far north as eastern Virginia. As it is variable in the amount of pubescence, some specimens being quite glabrous, and others having the stems and sheaths pubescent, and nodes barbed, it is possible that Elliott may have based his *P. microcarpon* on specimens of the pubescent form. Virginia: Curtiss; Bedford Co., 1873, sub nom. *P. nodiflorum* Lam. North Carolina: Ashe; Wilmington, 1895. Florida: Chapman; Apalachicola. Curtiss, Jacksonville, No. 4033.

47) *PANICUM LEUCOTHRIX* Nash, Torr. Bul. 24:41 (1817). Stems somewhat tufted, slender. 12'—30' tall, glabrous, or pubescent below. Sheaths shorter than the internodes, glabrous or the lower pubescent; ligule pilose. Leaves lanceolate, $1\frac{1}{2}$ ' long or less, 1"—2" wide, narrowed to the base, spreading or ascending. Panicle oblong, $\frac{1}{4}$ '— $1\frac{1}{2}$ ' long, the numerous short fascicled branches ascending; spikelets very numerous, less than $\frac{1}{2}$ " long, spheroid, whitish or purple.

Central Florida to North Carolina near the coast. Florida: Curtiss; Jacksonville, 5912. North Carolina: Ashe; Manteo, June, 1898. Related to *P. parvispiculatum*. This is Elliott's *P. nitidum*.

48) *PANICUM EATONII* Nash, Torr. Bul. 25: 84 (1898). Erect, 1'—3' tall, glabrous. Sheaths smooth: ligule pilose. Leaves lanceolate, taper-pointed, ascending, becoming much smaller towards top of culm, the largest 3'—4' long, and 4"—5" wide: panicle long-peduncled, oblong, 3'—5' long, the numerous short branches ascending; spikelets oval, about $\frac{1}{4}$ " long, first scale about one-third as long as the pubescent, 7-nerved second and third.

"Wet places along the coast, Maine to New York." Description based on material sent me by Mr. A. A. Eaton of Seabrook, N. H.

49) *PANICUM COLUBIANUM* Scribn. Bul. U. S. Div. of Agrost. 7: 78 (1897). Stems somewhat tufted, 8'—20' high, strict, glabrous or the lower pubescent: ligule pilose. Leaves distant, ascending, lanceolate, taper-pointed, the upper reduced in size, largest 2'—3' long.

3"—4" wide. Panicle long-peduncled, mostly smooth, 1'—2' long, at first contracted, later pyramidal, branches numerous, fascicled; spikelets broadly ovate, $\frac{3}{4}$ " long purplish, first scale minute, second and third 7-nerved, pubescent. Later stages fasciculate branched, the small branches and leaves ascending.

Too close to *P. nitidum*, from which it is distinguished only by its smaller size, and smaller panicle. New Jersey: Commons; 1897. District of Columbia: Kearney; June, 1897.

50) *PANICUM NITIDUM* Lam. Encl. 4; 748 (1797). Stems often tufted, erect, strict, 10' to 3½ feet high, nearly glabrous; later stages much branched from the sheaths. Sheaths shorter than the internodes, glabrous or with soft ascending hairs, or, to the southward, the lower sheaths papillose-hirsute; ligule pilose. Leaves firm, ascending, 7—9-nerved, oblong-lanceolate, 2'—4' long, 3"—4" wide, glabrous, or appressed pubescent beneath, shorter than the internodes; upper much reduced. Panicle 2'—3' long, broadly oval, at least the lower branches ascending, spikelets numerous, on very slender pedicels, about $\frac{3}{4}$ " long, broadly ovate.

New England to North Carolina, and Wisconsin. Its distribution farther westward undetermined.

District of Columbia: Kearney; 1897. North Carolina: Ashe; 1898. Wisconsin: Pammel; Prairie du Chien, 1891.

This is a very confusing and variable species. I have studied it in the field for three seasons and have carefully noted its variability. To the northeast, where it is common at least as far as New Jersey, it is generally glabrous or nearly so; to the southward it is often pubescent, with the sheaths papillose-hirsute, though the glabrous form occurs occasionally along with it. It is variable in size and in the shape and size of its spikelets, even on the same individual. The long pilose ligule, however, is constant. To the extreme southeast *P. leucothrix* occurs, which is closely allied to *P. nitidum*, and is the *P. nitidum* of Elliott. It is also very variable in its pubescence and in the size and shape of its spikelets. In the extreme west *P. nitidum* is represented by *P. thermile* Boland, a rather low, nearly glabrous species; while closely allied to it is a very villous form with larger, narrower spikelets, which seems to be specific. Its description follows:

51) *PANICUM HUACHUCAE* Ashe, sp. nov. Stems somewhat clustered, erect, slender, villous, 2 feet to 3 feet high. Sheaths shorter than the internodes, villous to papillose-hirsute; ligule long-pilose. Leaves erect or ascending, 3' -4' long, 3" -4" wide, generally villous, oblong-lanceolate. Panicle 3'-5' long, oval, pubescent; spikelets nearly 1" long, oval, or elliptical, pubescent.

Based on: Lemmon: *P. dichotomum* var. *nitidum*; subvar. *barbulatum*; Huachuca Mountains, Arizona, 1882. North Carolina: Ashe; Chapel Hill, June, 1898. Iowa: Bessey; Ames, 1875. Delaware: Commons; sub nom., *P. lanuginosum*. Missouri: Glatfeller; St. Louis, 1897.

52) *PANICUM VISCIDUM* Ell. Sk. 1: 124 (1817). *P. scoparium* Mx. Flora 1: 49 (1803). Not Lam. (1797). Tufted, large and stout, 2 feet to 3 feet high, ascending, from a generally geniculate base; stem pilose, especially below. Sheaths shorter than the internodes, pilose on the lower part, the upper generally viscid, barbed at the nodes, with a naked viscid ring below the node; ligule of very short pubescence. Leaves 3'—5' long, 4"—7" wide, lanceolate or narrower, narrowed to the base, glabrous above, generally pilose beneath. Panicle short-peduncled, 2'—4' long, broadly oval, the numerous, fascicled branches ascending; spikelets broadly obovate or nearly spherical, 1½" long, apiculate; axis of panicle often viscid. Later state much branched.

New Jersey to Florida and Texas. Frequent in wet or moist sandy places. Florida: Chapman, Apalachicola. Delaware: Canby, 1894. Texas: Reverchon. North Carolina: Ashe, 1897.

53) *PANICUM CILIIFERUM* Nash, Torr. Bul. 24: 195 (1897). Culms tufted, erect or ascending from a geniculate base, the joints geniculate. 18' -- 24' high. more or less villous below with appressed or ascending hairs, above smooth. Sheaths much shorter than the internodes, villous with soft, appressed pubescence; pubescence of ligule very short or sometimes long and villous.

Stem leaves erect or ascending, long-acuminate, broadest near the somewhat rounded base, the lowest lanceolate, 2'—4' long, 4"—5" wide, 9—13 nerved, the upper much reduced. Panicle pyramidal, 2'—4' long, the fascicled branches very long and slender, spreading or the lowest reflexed, spikelets purple, obovate, abruptly contracted at the base, 1" long, the first scale one-third the length of the smooth, 9-nerved second and third.

Shady pine lands. Eastern North Carolina to Florida. North Carolina: Ashe, Manteo, 1898. Florida: Curtiss; Jacksonville, 1897, No. 5866. Related to *P. arenicolum* but larger in every way, more pubescent, and with longer leaves.

54) *PANICUM TSUGETORUM* Nash, Torr. Bul. 25: 86 (1898). Stems tufted, 18' or less high, at first erect, and simple, at length much branched above and prostrate, pubescent with short ascending hairs, or with longer ones towards the base. Sheaths shorter than the internodes, pubescent with ascending hairs; ligule short, pubescent. Leaves lanceolate, the largest 2'—3' long, 3"—4" wide, later ones smaller, glabrous above, beneath appressed pubescent. Panicle broadly oval, about 2' long, the branches ascending; spikelets broadly obovate, about $\frac{7}{8}$ " long, pubescent.

Hemlock woods; Connecticut, and New York.

55) *PANICUM TENNESSEENSE* Ashe, sp. nov. Tufted, low, 5'—12' high, erect or ascending from a geniculate base, very slender, at first simple, soon densely branched above with short branches, glabrous or nearly so. Sheaths often nearly as long as the internodes, at least the lower ones covered with a short, soft pubescence; ligule short-pilose. Leaves spreading, thin, 3—5-nerved, the margins very rough, smooth above, beneath appressed pubescent and roughish, the largest $2\frac{1}{2}$ '—3' long, 3"—4" wide, widest in the middle, abruptly pointed, narrowed to the rounded base; secondary leaves thickly

crowded above, about 1' long, spreading, much longer than the very numerous, short, secondary panicles. Primary panicles short-peduncled, 1'—2' in length, oval, the spreading branches mostly single, rather few flowered, the slender peduncles two to many times the length of the obovate, pubescent, $\frac{3}{4}$ " long spikelets.

Related to *P. Joorii*, which it somewhat resembles. Based on No. 7087 Biltmore Herbarium: Cedar glades, LaVergne Co., Tennessee.

56) *PANICUM ATLANTICUM* Nash, Torr. Bul. 24:346 (1897). Culms tufted, erect or ascending from a usually geniculate base, 10'—20' high. Stem more or less pilose with spreading or ascending hairs, the nodes long-barbed above the naked ring. Sheaths pilose to villous, generally papillate, the lowest nearly as long as the internodes, the upper much shorter; ligule pilose, hairs 2"—3" long. Stem leaves ascending, above smoothish, below generally villous, the margins often ciliate with long hairs, 2'—3' long, 2"—3" wide, linear-lanceolate; narrowed at the somewhat rounded base, taper-pointed, middle leaves the longest; basal leaves much shorter; the later leaves on the secondary branches, ascending, one-half the length of the primary, smooth. Panicle 2'—3' long, nearly as wide, long-peduncled, the branches somewhat ascending, spikelets rather numerous, obovate, acute, quite 1" long, the first scale full one-third as long as the minutely pubescent 9-nerved second and third; later panicles not expanding, one-half the length of the surrounding leaves.

New York to North Carolina, and probably farther southward, generally near the coast. Delaware: Commons; 1872. North Carolina: Ashe; Cape Hatteras, 1898.

57) *PANICUM SCOPARIOIDE* Ashe, sp. nov. Stems single or a few together, erect, columnar, 16'—20' high, appressed pubescent. Sheaths papillose-pubescent, with ascending or appressed hairs, the lower much shorter than the internodes, the upper longer; ligule pilose.

Leaves linear-lanceolate, spreading and ascending, 2'—3' long, about 3" wide, rounded at the base, generally 9-nerved, beneath appressed pubescent, above glabrous, lower leaves distant, the upper approximate. Panicle 1½'—2' long, broadly oval, the branches fascicled, spreading, spikelets rather numerous, broadly obovate, somewhat over 1" long, apiculate, the acute first scale scarcely one-third the length of the nearly smooth 7-nerved second and third.

A species with the habit of *P. scoparium*, and spikelets which are nearly the size and shape of those of *P. viscidum*. Based on No. 283, ex Herb. A. Commons. Dry soil, Centreville, Del. June, 1873. Distributed sub nom. *P. Scribnerianum* Nash.

58) *PANICUM VILLOSSISSIMUM* Nash, Torr. Bul. 23: 149 (1896). Stems erect or ascending, tufted, slender, 16'—24' high, villous with long, ascending hairs, barbed above the glabrous nodes, joints geniculate. Sheaths much shorter than the internodes, villous; ligule pilose. Stem leaves linear-lanceolate 2½'—4' long, 3"–4" wide, rounded at the base, ascending, longest about the middle of the culm, the upper scarcely reduced, more or less villous with spreading hairs; basal leaves much shorter and not conspicuous. Panicle 2½'—3½' long, equally as broad, the numerous slender branches fascicled; spikelets obovate, about 1" long on slender pedicels.

Collected by Dr. J. K. Small in the Ocmulgee river swamp in May, 1895. Related to *P. pubescens* and *P. haemacarpum*.

59) *PANICUM PUBESCENS* Lam. Encl. 4:748 (1797). Culms tufted 10'—20' high, slender, erect, joints geniculate, stem to base of panicle villous with long, white, spreading hairs, a ring of longer hairs above the joint, below which is a naked ring. Sheaths about one half the length of the internodes, villous with long white hairs, minutely papillate; ligule pilose. Stem leaves ascending, linear-lanceolate, gradually narrowed at the base, taper-

pointed, villous to sparingly hirsute, 7--9-nerved, the longest about 3' long and 3'' wide; upper leaves much reduced in size; basal leaves hirsute, shorter and broader. Panicle about 2 inches long, nearly as broad, the branches single or in pairs, spreading or ascending; spikelets somewhat obovate, obtuse, scarcely 1'' long, first scale one third the length of the pubescent, 7-nerved second and third; peduncled 2 to 3 times the length of panicle. The late form densely fasciculately branched and spreading.

Maine to Iowa, Georgia and Missouri. Very close to *P. implicatum*. Maine: Merrill, 1895. Georgia: Ashe; Atlanta, 1896. Iowa: Cratty; Armstrong, 1889, No. 1067. Missouri: von Schrenk; St. Louis, 1897.

60) *PANICUM COMMONSIANUM* Ashe, sp. nov. Stems clustered, erect, strict, 8'—16' high, below appressed pubescent, above glabrous or puberulent. Sheaths shorter than the leaves or the lower overlapping, the lower appressed pubescent with ascending hairs, the nodes densely barbed with short ascending hairs. Leaves glabrous, or sparingly ciliate near the base erect or ascending, narrowly lanceolate, gradually narrowed to the apex from near the base; $1\frac{1}{2}'$ —2' long, ligule pilose. Panicle $1\frac{1}{2}'$ —3' long, as broad, as long, the branches fascicled, spreading, long-peduncled, glabrous or the axis puberulent; spikelets 1'' long, obovate, or broadly elliptical, pubescent. Roots very long and fibrous.

Based on No. 341, Commons. Collected in drifting sands along the coast, Cape May, N. J. June, 1898. Related to *P. haemacarpum*.

61) *PANICUM HAEMACARPON* Ashe, sp. nov. Tufted, stems erect or ascending from a geniculate base, 12'—18' high, below villous with long spreading or ascending hairs, above sometimes smoothish. Sheaths shorter than the internodes, papillate, villose with long soft, spreading hairs; the nodes bearded with spreading or reflexed hairs.

Leaves erect or ascending, 1'—2' long, 2''—3'' wide, lanceolate, the middle ones longest, the upper much reduced, the lower pilose beneath, the upper pubescent with long scattered hairs on the upper surface, appressed pubescent, often papillate, beneath. Panicles 1½'—2' long, broader than long, the branches wide-spreading somewhat fascicled, rather few-flowered; spikelets 1'' long, broadly obovate, apiculate, the first scale one-third the length of the pubescent second and third. Spikelets generally red, or purplish.

Closely related to *P. villosissimum* from which separated by its generally ascending habit, erect leaves, the upper reduced, and shorter usually ascending pubescence. District of Columbia: Kearney; 1897. Ashe: North Carolina; Chapel Hill, 1898. Iowa: Carver; Jewell Junction, 1895, No 258.

62) *PANICUM ARENICOLUM* Ashe, sp. nov. Erect from a usually geniculate base, 10' to 24' high, pubescent, at least below, with soft ascending hairs. Sheaths shorter than the joints, pubescent with short ascending hairs. Stem leaves erect or ascending, longest near the base of the stem, much reduced in size upward, the largest 2'—3' long, 2'' wide, long taper-pointed, glabrous above, beneath more or less papillose-pubescent. Panicle long exserted, 2'—3' long pyramidal, the flexuous fascicled branches spreading, at length reflexed. Spikelets somewhat less than 1'' long, obovate, obtuse.

Intermediate in size, habit, and general characters between *P. ciliiferum* and *P. demissum*, smaller than the former and larger than the latter. Type material collected by the writer at Chapel Hill, N. C. June 1898, and later at several localities in the eastern portion of the same state.

63) *PANICUM LAXIFLORUM* Lam. Encycl. 4: 748 (1797). *P. Muhlenbergii* Nutt. in Herb. *P. acuminatum* Swarz. ex Muhl. Gram. Stems densely tufted, ascending or spreading or later reclining, 15'—20' long, smooth or somewhat pubescent. Sheaths very short,

one-third the length of the leaves. papillose-hirsute: ligule a mere margin. Stem leaves few, mostly near the base of the culms, ascending or spreading, narrowly lanceolate, very taper-pointed, narrowed at the base or somewhat rounded, 7 to 9-nerved, the largest 3'—4' long, 4''—5'' wide, the upper leaves, scarcely reduced in size, glabrous or hirsute with long white hairs, often with ciliate margins; basal leaves shorter but similar to those of the stem, ciliate-margined, often hirsute, very abundant, soft and lax. Panicle 3' to 4' long, obovate, the branches slender, lax; spikelets obovate, about 1'' long, the acutish first scale one-fourth the length of the very pubescent, 9-nerved second and third.

Late panicles included in very short sheaths which are not longer than the basal leaves. Primary culms do not become fasciculately branched. Color light green. Damp shady hillsides, Maryland and Kentucky to Alabama and Florida. The basal leaves form large tufts which remain green throughout the winter. It is one of the earliest spring species. April-July. West Virginia; Small, 1892. Florida; Curtiss, Juniper, 1895, No. 5537. Tennessee; Ruth, 1897. *Panicum caricifolium* Scribn. in herb. as distributed by Kearney (Washington, D. C., May, 1897) differs from this only in its somewhat smaller—quite $\frac{3}{4}$ '' long spikelets.

64) *PANICUM LANUGINOSUM* Elliott. Sk. 1:123 (1817). Stems ascending from a geniculate base, rather stout, 12'—24' long, villous below, pubescent above. Sheaths shorter than the leaves, the lower, at least, densely pilose with soft pubescence, the upper often glabrous, barbed above the naked joint; ligule a ring of long hairs. Stem leaves lanceolate, rounded at the base, spreading or ascending, the largest near the base of the stem, $2\frac{1}{2}$ '—3' long, 3''—4'' wide, 9—11-nerved, generally soft-pubescent beneath, glabrous above, or the lowest pilose on both sides, finely ciliate on the margins, particularly the upper ones toward the base; upper leaves much reduced in size. Panicle 2'—3' long nearly as wide, the numerous, fascicled, smooth branches ascending; spikelets small for size of

plant, about $\frac{3}{4}$ " long, obovate, very pubescent, first scale about one-third as long as the 7-nerved second and third. Peduncle twice the length of panicle.

Dry sandy fields, New Jersey to Georgia near the coast. Related to *P. viscidum*. Description based on plants growing at Chapel Hill, N. C. Delaware: Commons; Mt. Cuba, 1871. Washington, D. C.: Kearney; 1897. Ashe; North Carolina: Chapel Hill, 1898.

65) *PANICUM IMPLICATUM* Scribn. Bul. 11, U. S. Div. of Agrost. 43 1898. Culms erect, tufted, 12'—20' high, very slender, somewhat geniculate at the nodes. Stem, to base of panicle, more or less pubescent with short white hairs, barbed above the naked ring at the joints. Sheaths about one-half the length of the internodes, more or less hirsute, at least below; ligule a ring of hairs 2" long. Stem leaves ascending, linear-lanceolate, gradually narrowed to the base, 2'—3' long, about 3" wide, 7—9-nerved, more or less pubescent; basal leaves much shorter, nearly glabrous. Panicle 1' or more long, about as wide, the numerous slender branches spreading; spikelets obovate, apiculate, $\frac{1}{2}$ "— $\frac{3}{4}$ " long, first scale minute, one-fourth as long as the nearly glabrous, 7-nerved second and third. Color of plant green, often purplish. Late stages much branched above.

Northeastern States. Specimens examined: New Jersey; Commons, 1897. New York: Wiegand, Ithaca, 1893. New York: Ashe; Watkins, June, 1898. New York: Ashe; Courtland, Aug. 1898. Maine; Merrill, 1897. Its smaller leaves, more branched panicle, and smaller spikelets separate this plant from *P. pubescens* to which it is most closely related.

66) *PANICUM ANNULUM* Ashe, sp. nov. Stems erect, generally single, 18'—30' high, below pilose, above generally glabrous, purple. Sheaths shorter than the internodes, at least the lower soft-pilose, nodes barbed; ligule very short, pubescent. Leaves lanceolate, 3'—4' long, 4"—6" wide, narrowed to the rounded base, the lower pilose on the lower surface, the upper generally glab-

rous, purplish, spreading. Panicle 2'—3' long, oval, the fascicled branches spreading or reflexed; spikelets about $\frac{3}{4}$ " long, narrowly obovate, pubescent; the axis of the panicle generally viscid. The later stage much branched.

Dry rocky woods. Maryland to North Carolina and Georgia. Near Washington, D. C. Ward; 1892. North Carolina: Ashe; Chapel Hill, 1898. Georgia: Ashe; Stone Mt., 1896. Related to *P. barbdatum*, but has a smaller panicle, and is pubescent.

67) *PANICUM MERIDIONALE* Ashe, sp. nov. Stems 4'—8' high, densely tufted, erect or ascending, villous with ascending hairs, purplish, very leafy. Sheaths striate, villous with ascending hairs, generally shorter than the internodes; ligule pilose. Leaves numerous, erect or ascending, 1'—1½' long, about 2' wide, lanceolate, rounded at the base, beneath pubescent with short ascending hairs, above with a few scattered long hairs, or towards the base of the leaf villous. Panicle glabrous 1'—2' long, the branches single or a few together, ascending; spikelets elliptical or obovate, nearly $\frac{3}{4}$ " long, the first scale about one third the length of the glabrous second and third.

I have collected this species at two localities in North Carolina, Chapel Hill in June, 1898; and Jonas Ridge, Burke Co., June, 1893. As these two stations are far apart the plant probably occurs in other States to the north and south of North Carolina. Dry rocky woods. Very different from either *P. filiculme*, *P. implicatum* or *P. pubescens*.

68) *PANICUM FILICULME* Ashe, sp. nov. Stems tufted, or single, at first simple, later fasciculately branched above, erect, very slender, 6'—10' high, more or less villous with ascending hairs. Sheaths villous with ascending hairs, shorter than the internodes; ligule of very short pubescence or of long hair. Leaves narrowly lanceolate, 1½' long or less, 1"—2" wide, rounded at the base, the lower surface papillose, appressed pubescent, the upper nearly glabrous, hirsute, or merely the mar-

gins fringed with long erect hairs, the upper leaves reduced in size; secondary leaves smaller, longer than the panicles. Panicle long-peduncled, small, about $\frac{1}{2}$ ' long, the rather short branches, erect or ascending; spikelets broadly obovate, obtuse, about $\frac{1}{2}$ " long.

Dry soil, middle North Carolina to Georgia in the Piedmont plateau region. Related to *P. implicatum* and *P. pubescens*. North Carolina: Ashe; Chapel Hill, 1898. Georgia: Small; Stone Mt., Aug. 1895.

69) *PANICUM CILIATUM*. Ell. Sk. 1:426 (1817). *P. ciliatifolium* Kth. Stems erect, 8'—16' high, smooth, slender. Sheaths smooth; ligule not hairy. Stem leaves, one to three, lanceolate, 1'—2' long, 2"—3" wide, smooth except for the ciliate margins; basal leaves very numerous, broader and longer than the stem leaves, the entire margin ciliate with long hairs, otherwise glabrous. Panicle rather small, 1'—2' long, nearly as wide, the fascicled branches ascending or spreading; peduncles 4 to 5 times the length of the panicle, smooth, spikelets on very slender pedicels, 3 or more times their length, nearly 2" long, obovate, acute, the first scale nearly one-half as long as the smooth 7-nerved second and third.

Color pale green. Rather uncommon. Ditch banks and sandy swamps, eastern North Carolina to Florida. A beautiful species. North Carolina: Ashe; near Wilmington. 1897. Florida: Biltmore Herbarium; Apalachicola, No. 6022 a.

70) *PANICUM POLYCAULON* Nash. Torr. Bul. 24:200, (1897.) Stems densely tufted, 6'—10' tall, simple, nearly naked, at length somewhat branched, sheaths loose, glabrous, the margins ciliate, upper longest; ligule pubescent. Stem leaves ascending, lanceolate, the longest about 3' long, 4" wide, ciliate on the margins 7—9-nerved; basal leaves numerous, ciliate. Panicle about 1' long, its axis somewhat pilose; spikelets about $\frac{3}{4}$ " long, obovate, first scale about $\frac{1}{2}$ ' long, as the 7-nerved, glabrous second and third.

"The narrower leaves more slender culms, and smaller and glabrous

spikelets well distinguish this from *P. ciliatum* Ell., to which it is most nearly allied." Florida and Cuba.

71) *PANICUM LONGIPEDUNCULATUM* Scribn. Stems erect, somewhat clustered, 6'—10' high; sheaths villous with spreading hairs, or nearly glabrous inflated; ligule hairy. Stem leaves few, distant, ascending, 2"—3" wide, lanceolate, narrowed to the somewhat rounded base, soft pubescent on both sides, the margin ciliate; basal leaves rather numerous, as long and as wide as those of the stem, pubescent on both sides, ciliate on the margins. Panicle about 2' long, oval, the axis pubescent, branches fascicled, spreading, slender; spikelets obovate, barely $\frac{1}{2}$ " long, obtuse, the first scale one-half the length of the smooth 7-nerved second and third, pedicels 3 to 4 times the length of the spikelets.

Color pale green. Ditch banks and wet sandy places, eastern North Carolina to Florida. North Carolina: Ashe; Roanoke Island, June, 1898. Florida: Curtiss; Jacksonville. The basal leaves of this species, like those of *P. ciliatum*, are much more prominent than the stem leaves, and the stems, having rather few leaves, appear rather naked. The autumnal stage is not fasciculately branched.

72) *PANICUM MICROPHYLLUM* Ashe, sp. nov. Somewhat tufted, 8'—20' high, slender, ascending or reclining, glabrous or pubescent with long white ascending hairs. Sheaths glabrous or pubescent, very much shorter than the internodes; ligule pilose. Stem leaves distant, ascending, linear-lanceolate, 1' long or less, 1"—2" wide, generally more or less villous. Basal leaves crowded, 1' or more long, 3"—4" wide. Late forms somewhat fasciculately branched above. Panicle long-peduncled, about 1' long, the slender branches ascending; spikelets, $\frac{1}{2}$ "— $\frac{3}{4}$ " long very broadly obovate, the minute first scale acute, one-fourth the length of the 7-nerved second and third.

Related to *P. angustifolium*. Collected by the writer June, 1898, at Chapel Hill, N. C., in moist sunny woods.

73) *PANICUM BRITTONI* Nash. Torr. Bul. 24:194 (1897). Stems tufted, glabrous, very slender, erect, stiff. Sheaths, glabrous, very short; ligule pubescent. Leaves longer than the sheaths, few in number, the middle leaves longest, $1\frac{1}{4}$ long or less, less than $1\frac{1}{2}$ " wide. Panicle 1' long or less, branches rather few, spreading; spikelets obovate, obtuse, $\frac{3}{4}$ " long, pubescent.

Moist sand, in pine woods. Southern New Jersey.

74) *PANICUM GLABRISIMUM* Ashe, sp. nov. Culms very slender, 12"—20" high, tufted, erect smooth and glabrous throughout. Sheaths much shorter than the internodes, glabrous; no ligule. Stem leaves very short, distant, less than 1' long, less than $1\frac{1}{2}$ " wide, narrowed to the base, erect or ascending, glabrous or sometimes with the narrowed base sparingly ciliate. Basal leaves $1\frac{1}{2}$ ' long or less, 2"—3" wide, ascending, glabrous. Panicle, peduncled, about 1' long, quite as wide, branches wide-spreading; spikelets, broadly oval or spheroid, about $\frac{3}{5}$ " long, glabrous or nearly so, purple.

The type material was collected by me June 1898, at Manteo, Dare Co., N. C.

NATURAL SCIENCE OF THE ANCIENTS AS INTERPRETED BY LUCRETIVS.

F. P. VENABLE.

There is no work, coming from an ancient author, which gives so full a picture of the beliefs and theories of ancient times as to the physical side of nature as Lucretius'

poem *De Rerum Natura*. It is by reading this that one may get the best insight into the ancient habit of thought concerning natural phenomena and the poem can be recommended to all who are fond of tracing over again ancient by-paths and half-lost tracks.

I do not purpose in this review to deal critically with the philosophy of the poem but rather to note the explanations offered of the various natural phenomena observed. We need not boast of our great knowledge of to-day but it becomes more precious to us when we realize how painfully and slowly it has been won for us, and how through centuries of darkness we have come to clearer light.

A word or two concerning the poem itself and its author may not be amiss. Lucretius lived somewhere in the last century preceding the birth of Christ and the poem was published about the middle of that century. An Epicurean in philosophy, and a follower of the atomic school of Demokritos, his poem was written as an exposition of their systems and in their defence. It was intended to explain to the minds of men the true nature of things and free them from ignorance and superstition.

Perhaps the most striking feature of Lucretius' poem is the deep reverence shown in it for the majesty of nature. The greatest minds were those which interpreted nature and the divinest faculty possessed by man was that through which truth was discovered. Homer was to him preeminent among the poets because he was near to nature and her great interpreter.

Prof. Sellars has said of him:

"It is, however, in his devotion to truth that Lucretius more than in any other quality rises clearly above the level of his countrymen and his age. He thus combines what is greatest in the Greek and Roman mind, the Greek order of inquiry and the Roman manliness of

heart. * * * He unites the speculative passion of the dawn of ancient inquiry with the real observation of its meridian; and he has brought the imaginative conception of nature that gave birth to the earliest philosophy into harmony with the Italian love of the living beauty of the world."

This poem is, as Constant Martha calls it, the most ancient monument of the science of Rome.

Lucretius had the difficult task of transcribing the concise, dry philosophy of Epicurus into the language of a people who knew little of science and cared less for it, except in the form of some useful application, and it required great ingenuity to succeed in conveying the desired ideas in a language so deficient in the needed terms. There is perhaps no great originality shown by Lucretius in the subject-matter of the poem but his enthusiasm and intense admiration for his master made him throw his whole poetic spirit into the task and so to give life and vivacity to the dry bones of the system. With a truly Roman simplicity, as Martha says, he believed that he and his master had said the last word of science. He was confident that his theories had solved all the mysteries of the universe, many of which were after all but the creations of superstition and trembling ignorance. A similar statement is made triumphantly nearly twenty centuries later by Berthelot. In the preface to his *les Origines de l'Alchimie* he too maintains that science has done away with mystery. "*Le monde est aujourd'hui sans mystere.*" We smile at the solutions which Epicurus, through his devoted follower, offered of the phenomena of nature. Who can feel assured that some future generation shall not smile, with the same pitying superiority, over the ignorance and folly of Berthelot.

"But the old problems that have defied the thought of the ages still wait for a solution. When men inquire for

the origin of matter and how it is constituted, or for the origin of force and how it operates, the sphinx is dumb. When they attempt to get behind the phenomena of heat, electricity, magnetism, they are challenged by a sentinel they can not bribe nor force." *

On an examination of this poem the essential difference between the ancient scientific method and the present is revealed and with it the reason for much failure and little progress. Lucretius first announced his theory and then proceeded to fit it, forcibly if need be, to every fact that came within his observation. This process is reversed by the modern man of science. He first gathers his facts and from their study develops his theory. A mind already full cannot receive new truth. The emptied vessel is the only one which is ready for filling.

To the mind of Lucretius the "Universe is a real existence and absolutely dual in nature. Body and space, or matter and vacuum, are the two essential elements admitting no third. Bodies, are therefore, made up of atoms and pores. Neither can exist where the other is. The atoms are composite, yet, paradoxical as it may seem, are solid, single, indivisible and indestructible."

Know, then, the entire of Nature sole consists
Of Space and Body: this the substance moved
And that the area of its motive power.
Know, too that bodies, in their frame consist,
Part of primordial atoms uncombined,
And part combined and blending: these alone
Previous and rare; while those so solid formed
No force create can sever, or dissolve.

Now the task which Lucretius sets himself is to take this theory and by means of it explain the formation of the material world without the introduction of any creative intelligence, the genius of man and animals, the causative forces in all the natural phenomena and even

* Harrington. Meth. Quart. Rev. 1876. LVIII. 64.

the nature of such things as heat and light and of thought itself. In fact it is concerning the "nature of things" that he writes.

Let us see first how Lucretius reasons away the difficulty that his atoms cannot be detected by the sight and so brought within the reach of examination.

Learn now of bodies which you must confess
Exist in things, but yet nowhere can see.
First when incited winds o'er ocean sweep,
Dispersing clouds, o'er whelming mighty ships,
* * * * *
Thus secret bodies sure exist in winds
Which sweep the sea, the land, the clouds of heaven.
* * * * *
So various odors we perceive in things,
Yet naught material see the organ strike.
Nor heat, nor cold, nor sounds, can eye discern,
Though all of corpor'al nature must consist,
Since they the senses strike; for know, bodies
Alone can bodies touch or touched be.

Book 5 p. 46.

Again he very beautifully impresses the lesson, which he himself so imperfectly learned, that we must reason as to causes from their visible working.

Caverns deeply worn,
Where rocks impend o'er the corroding sea,
Show not the gnawing of each breaking wave:
For Nature acts on atoms hid from sight,
In secret working, but results reveals.

Book I p. 47.

See what proof he offers as to the existence of voids in matter. This was a very essential part of his theory and it is easy to see how convincing the phenomena must have seemed to such a materialist as Lucretius:

A void exists in things.
However solid bodies may appear,
Void spaces they contain, since water drips
In caves and grotts, and drops ooze out from rocks,
And all around with trickling moisture weeps
Sound traverses closed doors and solid walls
While stiffening cold strikes piercing through the limbs.
But were no void how could such bodies pass?
You needs must see it were impossible. Book I p. 48.

His explanation of the difference in the specific gravity of various bodies is based upon this theory of voids.

Why do some things excel in weight others
Of greater size? If equal matter be
In globe of wool and lead, why equal not
In what to matter most essential is—
Weight? Downward pressing to the void unknown,
The greater lighter than the less, thus prove
Existence of a void, the heavier still
Embracing less than light of spaces void.

Book I p. 49.

From his standpoint the weight was dependent upon density or compactness. From this it might be inferred that all atoms had the same weight.

The beautiful phenomenon of the condensation of moisture upon a cold surface is correctly explained if we disregard the description of a material nature and separate existence to cold.

Cold permeates the silver cup or gold,
With water filled, held brimming in the hand,
And dew-like moisture gathers on without.
Thus naught in nature solid seems to be.

Book I p. 53.

The doctrine of the indestructibility of matter has been commonly accredited to Lavoisier but a recent writer has shown that the saying attributed to him "*Rien ne se perd et rien ne se crée*" does not occur in his works and that at best he tacitly assumed this which had long been believed by others. Kahlbaum traces it to P. Mersenne the friend of Descartes but, it is easy to go many centuries back of this and to find the doctrine clearly stated in Lucretius. He writes of his atoms:

Nature reserving these as seeds of things,
Permits in them no minish nor decay;
They can't be fewer and they can't be less.

Book 1 p. 57.

Or again:

Decay of some leaves others free to grow
And thus the sum of things rests unimpaired

Book II p. 79,

And again:

The store of elements material,
Admits no diminution, no increase;

Book II p. 86.

No modern scientific man could state more clearly than Lucretius does, the ideas which prevail at present as to the motions of the atoms. Says Tyndall of the particles in a mass of iron: "There is space between them, they collide, recoil, they oscillate."

The poet states it thus:

No place of rest is found
To primal bodies through the vast profound,
And, finding none, they cease not ceaseless rounds.
Part forced together, wide asunder leap;
From closer blow part, grappling with their kind,
In close affinities unite and form
Bodies of various figure—varied forms diverse.

Book I p. 80.

Again:

For infinite atoms, in a boundless void,
By endless motions build the frame of things.

Book II p. 82

All things are made up of these atoms:

The same elements constitute the air,
The sun, the earth and animals and plants,
And other things by union various.

Book I p. 63.

Lucretius makes much use of what he calls the "seeds of heat," that is, the atoms which by their concurrence form heat. Thus he explains the heat resulting from friction.

The neighbor top of trees swayed by the wind
Are creaking rubbed, till by attrition they
Burst into flower of flame; not that the fire
Dwells in the wood but rather seeds of heat

By friction forced to flow, together run,
 And bursting barriers fire the leafy tops.
 For sure, if latent lay the flames in wood,
 Not long could they be hid, but, bursting forth,
 Would ravage forests, burning every shrub

Book I p. 63.

He is an avowed opponent of the ordinary view of gravitation. In common with his countrymen, he thought lightly of mathematics.

Guard against belief
 Of what some say, "that to the centre tend
 All things, and thus the world can stand
 Without external impulses and shocks."—Book I, p. 71.

Are we to look upon the following passage as a prediction of the discovery of argon and its strange companions? Speaking of his atoms he says :

And some there are wide wandering in space,
 That all affinities reject, nor can unite
 With any body in a common bond.—Book II p. 81.

He puzzles over one of our deep problems, the co-existence of sovereign law and the free will of the creature.

Again, if all motion in a chain were bound,
 If new from old in fixed order flowed,
 Cause linked to cause in an eternal round ;
 If atoms' no concealed clinamen had
 Cause to create, and break the bond of fate,
 How could free-will in animals exist?

In speaking of the dissimilarity in atoms he discusses the nature of fire and cold. His conclusions are somewhat startling :

How different is fire from piercing frost!
 Yet both composed of atoms toothed and sharp
 As proved by touch. Touch, O ye sacred powers!
 Touch is the organ whence all knowledge flows:

Book II p. 90

His theory as to the three physical states is that solids are made "of atoms hooked like branches deep entwined"; liquids, "of bodies round and smooth must be composed";

"while those that in an instant are dispersed, and flee away, as smoke, or clouds, or flame," are formed of "sharp and not of atoms hooked since pores they penetrate."

The dependence of color upon light is well recognized "without light no color can exist." Atoms are colorless and not subject to the rays of light,

He has noted that

The more minutely things divided are
The more their colors fade.

He has observed that light traverses space more rapidly than sound,

Far quicker comes the impulse to the eye
Than to the ear :

Book VI p. 263.

There is an interesting passage in the works of Van Helmont in which he describes the artificial generation of mice from a soiled shirt placed along with some flour in a barrel or other vessel. The method sounds plausible and doubtless an experiment along that line would result in mice in the barrel. But too much credit must not be ascribed to Van Helmont as the original discoverer for after all his ingenious idea was not original. Our poet of the last of the old centuries says ;

Facts manifest
Confute not but confirm and force belief,
That all the living from the lifeless springs ;
For see live worms creep from the putrid clod,
When the warm earth is wet with timely showers.

Book II p. 106.

Darwin might have gotten an idea or two from our ancient philosopher for his "Observations upon Earth-worms".

Lucretius' ideas as to life, disease and death are also instructive. Men of deeper learning than he have wrestled with this problem of Life and Death with equal

failure. The best of modern thought agrees with him in one sense at least when he says:

“And life itself is but a part of death.”

Death he believes comes from some shock which shatters and destroys the union of the atoms. The shock theory of fermentation and decay was vigorously maintained and defended during the first half of this century.

Then when some greater shock a life assails
Than Nature can support, sudden all sense
Of mind and body is confused and stunned.
The ordering of elements dissolved,
Their bond of union snapped, the silver cord
Is loosed, the vital tide turned back, and life
With all its elements dispersed. But what
Can blows do more than shatter and dissolve
What once was joined?

Book II p. 108

Liebig in 1852 reasoned that contagion was due to gaseous matter in a state of decomposition. Disease is excited by contagion. According to the “law of La Place and Berthollet: *A molecule* set in motion by any power can impart its own motion to another molecule with which it may be in contact. The motion of these decomposing molecules is transmitted to the blood and if decomposition there is not overcome it proceeds over the entire body.” This reads almost as strangely as the words of Lucretius. It is only just to Liebig to add that he acknowledged his errors afterwards and accepted the theories of Pasteur and Schützenberger.

Lucretius’ theory of contagion would sound very much like the modern germ theory if only his seeds were endowed with life.

First, then the air teems, as I’ve taught, with seeds
Diverse, some favoring life, but many more
Fraught with disease and death; chance gathered, these
Infect the sky, malignant make the air.

Lucretius has anticipated the recent address of Sir

William Crookes, the learned President of the British Association for the Advancement of Science, by more than nineteen centuries in the prediction of the exhaustion of "the worn-out Earth." True he did not fix upon 1931 as the date of complete exhaustion still he evidently did not think it very far off. Like all sturdy conservatives he praised the good old times.

E'en now the worn-out earth with age effete,
 * * that in her early prime * * *
 To children of her care spontaneous gave--
 In rich abundance gave the shining grain,
 Which now with labor huge she scant supplies
 In niggard pittance to more pressing wants,
 With weary steps we urge the weary ox,
 And turn exhausted fields, that scarce return
 Decreasing harvests to increasing toil.
 The aged ploughman shakes his weary head
 So oft his labor unavailing proves:
 How oft doth he then repining chide his lot
 Comparing present times with past, exalt
 The fortune of his sires.

Book. II p. 114.

He gives a remarkable explanation of the nature of reflected images. These are made up of

Thin effigies and forms
 Which singly are unseen; but when outpoured
 In a continuous and impulsive flow,
 Give by reflection, images of things.

These effigies "wander not alone." They "fill the embracing air with floating forms." This is proved by the fact that in whatever direction the mirror is turned, "straight in its silent depths the scene responds." The reversal of the image in the mirror is explained at some length. The image itself suffers change on turning back from the mirror.

As when the plastic mask of wax, or clay,
 Dashed sudden 'gainst a wall, backward reverts,

The well-recognized law that the angle of reflection is equal to the angle of incidence comes from Lucretius thus:

For with what slope
They fall, Nature compels them to revert again.

Peter Schlemihl, the famous shadowless man of Chamisso would have been wondrously relieved if he could have read Lucretius and learned,

The obsequious shadow that attends our steps,
When walking in the sun seems of itself
To walk with us and every gesture mock
Yet nothing is but space, deprived of light

Book IV p. 169.

If we accept Lucretius' theory that "all sounds corporeal are," then it is easy to account for prevalent sore throats:

And voice escaping to the sphery air,
Roughens the throat, abrades the passages.

"Whence come our mental images" is surely a most important question to settle but one before which the boldest is apt to hesitate.

There is no such hesitancy about Lucretius, however. "Innumerable idols float in space." These are many subtle and of finer texture than the "attenuate thread of spider or the roof of filmy gold." These

Through rarer pores can penetrate.
And sentient make the mind in inmost seats.

Book IV p. 181

Any one inclined toward materialism can read with interest the intense materialism of this old Epicurean. His cosmogeny is brilliantly fanciful. As to the sun it is neither greater nor less than it appears and this is true also of moon and stars. Whether the sun returns by a course beneath the earth or whether it is exhausted by its day's course and its place is taken by a new one, formed by the collection of "dispersed seeds of heat" he does not venture to decide. Eclipses and the moon's phases are also discussed. The struggle for existence is pictured and something very similar to the doctrine of the survi-

val of the fittest is announced. Thunder is the rushing together of several clouds "driven by warring winds." The nature of clouds he discusses at great length. Some of these phenomena have puzzled men all through the ages and it is not necessary to point out how imperfect our knowledge still is.

The interior of the earth is constituted as the surface and hence contains caves, lakes etc. The falling in of such caverned depths cause the earthquakes. In these caverns the air in motion "makes glow the rocks around." Winged flames then "vomit from wide open jaws" hurl rocks, and send out cinders and smoke, and so volcanoes are formed. The constancy of the volume of the sea was observed by Lucretius and correctly accounted for.

A strangely mistaken observation as to the temperature of wells is mentioned and of course his theory is made to cover and explain it. Such waters were thought to be cold in summer and warm in winter. This was, of course because what we may call the personal thermometer registered largely the relation to the temperature of the atmosphere.

I have not been able to exhaust all of the observations recorded by this early philosopher, nor to properly show his ingenuity in fitting his theory as to atoms and the "seeds of things" to every case. Nor has it been possible to give a just idea of the grace and poetic beauty of this the first and only attempt to bring all of natural science within the limits of a single poem.

WORKS CONSULTED IN THE PREPARATION OF THIS ARTICLE.

- 1 T. Lucretii Cari, *De rerum natura*, ex editione Gibb., Wakefieldi, Valpey's auctores classici.
- 2 Lucretius, *On the Nature of Things*. A philosophical poem, translated by Rev. John L. Watson, with the metrical version by John M. Good.

- 3 Lucretius, *On the Nature of Things*. Translated into English Verse by Charles Frederick Johnson. The passages quoted are taken from this work.
- 4 *Le Poëme de Lucrèce, Morale, Religion, Science* par Constant Martha.
- 5 *The Atomic Theory of Lucretius contrasted with Modern Doctrines of Atoms and Evolution*, by John Masson.
- 6 *Lucretius*, by Prof. Harrington, *Methodist Quarterly Review*- 1876, p, 64.

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ON THE FEASIBILITY OF RAISING SPONGES FROM THE EGG*

H. V. WILSON.

For the purposes of scientific investigation the problem suggested in the title of this paper presents no difficulties to the zoologist. Whether, on the other hand, it is practicable or even desirable to rear sponges from the egg for the purposes of the sponge-grower, is a question which can only be decided by experiments carried on continuously for some years. From the standpoint of the scientific breeder such experiments seem eminently desirable, and the probability that they would result in economic discoveries of importance is very great. It is my purpose to point out, toward the end of this paper, some of the advantages attainable, as I believe, by this method of breeding. I shall preface my remarks on the rearing of sponges with a brief account of the manner in which the egg development goes on.

*Extracted from "Proceedings and Papers of the National Fishery Congress held at Tampa, Fla., Jan. 1898," published in Bulletin of U. S. Fish Commission, Washington, 1898.

Some sponges are known to be hermaphrodite, others have been described as of separate sexes. The probability is that sponges are in general hermaphrodite, but that the individual at one period produces chiefly male elements, and later chiefly female elements. Fertilization takes place in the body of the mother and the egg here undergoes early development. The embryo eventually bursts the maternal tissue, and, passing into one of the canals, is caught by the current sweeping through the canal system and is discharged into the surrounding water through one of the large apertures (oscula) on the surface of the sponge.

In the great majority of sponges (horny and silicious forms) the embryo, or larva as it now should properly be called since it leads a free life, is an oval, solid body, covered with slender hair-like processes of protoplasm, the so-called cilia. The cilia strike rhythmically to and fro, like so many minute and flexible paddles, and the sponge larva is by their means whirled through the water. Sponge larvae, of course, vary in size, but frequently have a length in the neighborhood of 1 mm, (.04 inch). The surface layer contains more or less pigment. Thus in the commercial sponge, *Euspongia*, the larva is whitish, with a brown spot at one end. In *Tedani brucei*, a large red sponge, growing especially on the mangroves in parts of the Bahamas, the larva is a beautiful red.

The free swimming life of the sponge larva is short lasting, when bred in the laboratory, only a day or two. During this period the larva is moved not only by its own relatively feeble motion, but, being subject to the action of the currents, it may be carried a considerable distance from the spot where it was born. It eventually settles down on some firm basis and transforms. The cilia are lost, and the oval body flattens out into a disk so thin that it

has the appearance of a minute incrustation. The circular outline of the disk is soon lost, the little sponge spreading in an irregular fashion over the surface to which it is now firmly attached. In two or three days the metamorphosis is complete, and we have a sponge, very small to be sure, and without reproductive elements, but like the adult in fundamental structure. Its surface is perforated by minute apertures, the pores, through which the water enters the body, and by a few larger apertures, the oscula, through which the water leaves the body. Ramifying through the interior is a system of spaces or canals which connect the pores with the oscula. Portions of this canal system form spheroidal chambers, the walls of which are studded with cilia. It is owing to the motion of these internal unseen cilia that a current of water is constantly circulating through the sponge body, carrying to its tissues the oxygen and food (minute particles of animal and vegetable organisms) necessary for their life.

How long it takes for a sponge developed in this way to reach adult size and begin breeding is unknown. I have kept young sponges that have transformed and attached to the walls of my laboratory aquaria for days and weeks. After the first few days the increase in size has generally been imperceptible. But the unfavorable conditions incidental to such an unnatural habitat were doubtless responsible for this lack of success.

PRACTICAL SUGGESTIONS ON REARING SPONGES

More species of sponges breed during the warm season than at other times. Yet in the Mediterranean Naples, some sponges are found breeding at all times of the year. In the Bahama Islands and on our own coast, I have found the breeding time of many sponges to fall within the period from midsummer on through early autumn. For

the inauguration of experiments I should recommend the months of July, August, and September.

It is easy to determine when one of the horny or silicious sponges is breeding. On cutting out a piece of the sponge, the developing eggs scattered through the tissues can be seen without the help of a lens. They are minute, rounded bodies, often very numerous, and sufficiently conspicuous to catch an observant eye.

The means employed for getting young sponges must always be different from those made use of in the case of animals like fish, oysters, etc., in which artificial fertilization is practicable. Since the sponge egg is fertilized and undergoes its early development in the body of the mother, artificial fertilization is here of course out of the question.

The young in numbers ample for study can, however, be obtained in the following easy manner. The sponge being raised to near the surface of the water is then dipped up in a glass aquarium or bucket, in such a way as not to expose the animal to the air. In a few minutes time the ciliated larvae will begin to be discharged. In the study of some Bahama sponges I found it convenient to take to the sponge-grounds, in a boat, a couple of good sized tubs. In one of these some sponges would be placed for about half an hour. At the end of that time they were transferred to the second tub. The water of the first tub was meanwhile examined for the sponge larvae. In this I was aided by negro boys, who soon became expert. We bailed out the water in 2-gallon glass vessels in which the little larvae could readily be seen. The latter were then picked out with glass tubes and placed in a special dish. By the time the examination of the first tub was completed, the second would be found to contain numbers of larvae. These were collected in the same way, the sponges being thrown overboard.

It would seem in the case of sponges, as with so many marine animals, that the stimuli arising from confinement in a limited volume of water lead to the rather sudden discharge of those embryos (or in certain forms, eggs) that have reached the proper stage for birth.

I have no doubt that if the sponge were handled carefully, it would be possible to get from the same individual, day after day during the breeding season, numbers of larvae, precisely as several batches of eggs are got from one codfish, for example.

The swimming larvae thus obtained may be made to attach, during the next day or two, to the walls of the dishes in which they are kept, or to pieces of wood or small stones. After attachment the young, or, as we might say, the sponge "spat," are easy to handle. In this connection, however, it will be well to bear in mind that the circulating pipe water of aquaria, even large and elaborate ones such as those at Naples and Woods Holl, has been found to be unsatisfactory for the rearing of young sponges, as indeed it is for the young stages of many marine organism. The sponges become covered with sediment, and bacteria develop. Changing the water in the dishes twice a day is, on the whole, a better method. But this is far from an ideal environment. It will probably be much better, after the attachment of the spat to pieces, of wood, shells, etc., at once to transfer the latter to some natural site known to be adapted to the growth of sponges.

I hardly think the method of getting young sponges which I have just described can ever be adapted to the needs of the sponge-grower. And yet for the purposes of experiment, where a few hundreds or a thousand young sponges would suffice, the method is adequate. I believe, however, that live-boxes may be devised in which the sponge may be kept imprisoned in its natural home,

though at some convenient depth, and in which the discharge of larvae may go on normally day after day. Such a box must have fine metal gauze windows on the sides and above, through which water may pass freely, and yet with meshes sufficiently fine at any rate to hinder the passage of the larvae through them. Projecting shelves, which must be easily removable, might be arranged one above the other. The sides and bottom of the box should, moreover, be covered with removable pieces—tiles, for instance. The larvae settling down on the removable shelves or other pieces would attach to them, and might from time to time be taken out with as much ease as the honey stored up in the modern manufactured comb; is removed from the hive.

The precise form of live-box to be used will naturally only be determined after proper experiments. To prevent as far as possible the settling of the larvae on the body of the mother, a phenomenon very apt to occur, it will perhaps be found well to place the adult on a perforated tray near the top of the box, and a series of such trays, one above the other, may be found a good device. In planning experimental boxes of this sort, the character of the motion of the sponge larva should be borne in mind. The larva not only swims, frequently making long, shallow dives, but also creeps about over the sides and bottom of the vessel in which it is kept.

The live-box has proved itself of great use to the naturalist desirous of obtaining the young stages of animals, which are difficult to keep or breed in the laboratory. In this connection I well remember the experience of a companion (Prof. C. L. Edwards), engaged in the study of the development of the large holothurian or sea-cucumber (*Mülleria*), so common in parts of the Bahama Islands. It was with the greatest difficulty that a few embryos of this form could be got in the laboratory.

When, however, the animals were confined in a large box anchored in about a fathom of water, quantities of developing eggs could be had by drawing up with a tube some of the sediment in the bottom of the box.

The "spat" once obtained in abundance, success will next depend largely on the selection of the locality in which the young sponges are to be set out. A careful study of the Florida grounds should be undertaken, with the view of investigating, among other points, this very matter of the kinds of locality best adapted to the growth of the various grades of sponges. Quiet water, a firm bottom, and an absence of muddy sediment seem essential desiderata. The question of enemies is probably of minor importance, and yet the well-known student of sponges, Vosmaer, mentions that he has several times seen the European hermit-crab (*Pagurus*) greedily eat a common silicious sponge (*Suberites*), certainly quite as unappetizing a morsel as the commercial sponge.

When it has once been accurately determined what are the physical and biological characteristics of the Florida grounds, which produce the finest sponges—and it may be mentioned here that sponges are among the most variable of animals and seem to be peculiarly affected by their surroundings—a detailed comparison should be made between these grounds and those parts of the Mediterranean producing the finest grades. The purpose of such a comparison would be to discover whether we really lack any of the natural advantages necessary for the production of the finest sponges, and if so, whether these can be artificially reproduced whether for instance it would be possible or desirable to imitate on this side a particular kind of bottom found in the Mediterranean.

Following on the investigation of the sponge-grounds,

I believe it to be eminently desirable to start a series of experiments, the purpose of which shall be to discover how far, along what lines, and by what means sponges may be artificially altered by breeding. The great variability of sponges in nature leads one to believe that they would quickly respond as individuals to a change in the environment, and thus, simply by growing the animals in a superior locality, an improved variety, constant, as long as the sponges continue to grow in that locality, might be produced. It is quite likely that such improvements could be carried out on sponges propagated by cuttings as well as on those grown from eggs. In improving races, however, it has always been found that the two important means are sexual breeding from selected specimens, and grafting, the latter method being commonly regarded as only applicable to plants.

In the case of sponges, as in that of other organisms, increase of knowledge will in all probability confirm the belief already fairly well grounded, that individuals developed from the fertilized eggs vary more, i. e., exhibit more differences one from the other, than individuals grown from buds or cuttings. Herein, to my mind, lies the advisability of growing sponges from eggs as well as from cuttings. The latter method, being quick, sure, and simple, can at once be made of great practical use. Breeding from the egg is more complex, and must be carefully tried by competent experimenters. In the end, however, I believe that it will lead to great improvements in the quality of our sponges.

I would suggest that, after selection of a proper locality, a small plantation of sponges developed from eggs be started and carefully watched. As the sponges grow, it would be a simple matter to pick out those individuals in which the fiber varied in the desired direction. A small

piece cut out would not seriously injure the sponge, and would show the quality of fiber as well as the entire body. Selected individuals might be removed from the general ground and during the breeding season placed together in large live boxes. The "spat" collected from such individuals would doubtless develop into superior sponges. I do not know any marine animals which would seem to be so adapted to continuous rearing, with constant improvement of breed, as sponges. Their plant-like habit of growth make it easy to handle and experiment upon them. Their variability, especially in the matter of the skeleton, would seem to insure success to selective breeding; and the very simplicity of what is desired, namely, improvement in the quality of the skeletal fiber, would at once lend a directness to the cultivator, which should lead to comparatively early results.

In closing, I may direct your attention to a method of race improvement, so far practiced only in the cultivation of plants, but to which the vegetative character of sponges will readily lend itself. I refer to the method of grafting. The ease with which two or more individuals of the same species of sponge, irrespective of age, may be made to fuse, and become henceforth a single individual, is well known. Dr. Grant records observations on this head as far back as 1826. Among later experimenters I will only mention Vosmaer. This fusion of individuals goes on commonly in nature. An interesting account of a number of cases may be read in Johnston's *British Sponges and Corallines*, published 1842, page 11.

The natural tendency of sponges to grow together, coupled with the ease with which they may be propagated by cuttings, would make artificial grafting in these animals a simple matter. With a small plantation of very superior sponges at hand, the result of careful breeding from selected individuals, and other plantations consisting fo

sponges grown from cuttings, grafting ought to be not only a scientific but an economic success. At slight expense large numbers of common sponges might be improved, simply by pinning to the common cutting a piece of the improved variety.

A REVIEW OF CONANT'S MEMOIR ON THE CUBOMEDUSÆ*

H. V. WILSON.

Memoirs from the Biological Laboratory of the Johns Hopkins University, IV., 1. *The Cubomedusæ*. A Dissertation presented for the Degree of Doctor of Philosophy, in the Johns Hopkins University, 1897. By FRANKLIN STORY CONANT. A Memorial Volume. Baltimore, 1898.

The late Dr. Conant, it will be recalled by many, was a member of the marine laboratory of the Johns Hopkins University, stationed during the summer of 1897 at Port Antonio, Jamaica. Toward the end of the season's work fever broke out. The director of the expedition, Dr. J. E. Humphrey, died in a sudden and alarming manner. Dr. Conant assumed charge of the laboratory, and, though aware of his own great danger, remained in Port Antonio, devoting himself to the service of others who needed his help. This generous subordination of self cost him his life, for he contracted the fever, and, though able to reach this country, he died a few days after his arrival in Boston.

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Dr. Conant's many friends, well aware of his candid, judicial mind, his keenness and persistency in observing and in reasoning from observations to a conclusion, have entertained the highest expectations of the work he was to do for science. Cut off at the beginning of his career, he leaves behind him several smaller papers and the dissertation before us. On closing this volume the author's friends will feel confirmed in their high opinion of his abilities, and those who did not know Dr. Conant will realize with regret that an able and conscientious naturalist has been removed from our midst.

Dr. Conant's dissertation, published as a memorial volume by his friends, fellow students and instructors, with the aid of the university in which he had recently taken his doctor's degree, deals with the anatomy and classification of one of the most interesting groups of jelly-fish, the Cubomedusæ. In this group, embracing but a small number of species, the scyphomedusan structure, with which most of us are chiefly familiar through the study of *Aurelia*, *Cyanea* or *Dactylometra*, is in general presented as destitute of the complications which characterize the more common forms. This simplicity in general structure places the group close to the stem-forms, *Tessera* and *Lucernaria*, themselves scarcely more than sexually ripe *Scyphistomas*, and makes a comparison with existing Actinozoa an easy matter. Curiously enough, the members of this primitive group possess the most highly developed sense-organs as yet described among coelenterates, the nervous system being correspondingly differentiated. In one other respect the Cubomedusæ are unique, in that they alone among the Scyphomedusæ possess a velum. The phylogenetic origin of this velum (velarium) has been the subject of some discussion, the balance of opinion inclining to the belief that it has arisen through the fusion of marginal lobes similar to those

found in the Peromedusæ and the Ephyropsidæ (*Nausithoë*), and is merely analogous to, not homologous with, the velum of the Hydromedusæ. That this is the case is borne out by the presence in the velum of gastrovascular diverticula. This resemblance to the Hydromedusæ is regarded by most naturalists as one of the numerous cases of convergent evolution exhibited by the two groups of jelly-fish (Hydro- and Scyphomedusæ), due to similarity in environment and to a certain similarity in the ancestral polyps from which the two groups have been derived.

The Cubomedusæ are so rare that in spite of their interesting features, interesting alike to the student of phylogeny and nerve-physiology, few naturalists have had the opportunity of studying them. Our knowledge of the group has rested mainly on Claus's description of *Charybdea marsupialis* (Wien. Arb. 1878). This very valuable paper, as Conant remarks, is written in a style difficult of comprehension, and many students who read with pleasure and profit the lucid treatises on medusan structure by the Hertwigs and Haeckel have turned away discouraged from Claus's work. To Claus's account, Haeckel in his "System" has added but little. The only other investigator of the group is Schewiakoff (1889), who has studied the remarkable sense organs.

Through Conant's discovery in 1896 of two new species (*Charybdea xaymacana* and *Tripedalia cystophora*), which are present in abundance in Jamaican waters, the Marine Laboratory of the Johns Hopkins University has once again made accessible to students, material for the pursuit of investigations of wide interest. It was for the purpose of continuing his study of this group that Conant, in the summer of 1897, revisited Jamaica, and, as we learn from Professor Brooks's introduction, he succeeded in making many observations on the physiology of the

sense-organs and on the embryology. His notes and material, we are told, are in such shape that they can be handed over to some else, and it may be safely predicted that a valuable contribution to science will be the outcome of the last summer's work of this talented young naturalist.

The account of the cubomedusan structure given by Dr. Conant is succinct, but comprehensive. The deep, four-sided bell bears a tentacle (or in some species a bunch of tentacles) at each angle. On each lateral surface, at a higher level than the tentacles, is situated a niche into which projects a sense-organ. The primitively undivided (*Scyphistoma* condition) gastrovascular space is here differentiated into a central stomach and a peripheral portion lying in the lateral wall of the bell. The peripheral portion is subdivided into four stomach pockets by linear partitions, lying in the plane of the tentacles and therefore interradial. These partitions (*cathammæ*) are mere strips of entodermal lamella, produced by the fusion between the entodermal lining of ex- and sub-umbrella. The *cathammal* lines stop short of the tentacles, leaving an undivided peripheral portion of the primitive space, by means of which the four stomach pockets communicate with one another. As Conant points out, the arrangement recalls the gastrovascular system of many *Hydro-medusæ*, with the difference that in the *Cubomedusæ* the radial canals are wide 'stomach pockets' and the *cathammal* plates are narrow lines. When we come, however, to the extreme peripheral portion of the gastrovascular system, we find that the likeness is not with the *Hydro-medusæ*, but with the lobed *Scyphomedusæ*. The gastrovascular space, to be brief, does not end with an even circular edge at the bell margin, as is the rule in the former group, but is divided into separate lobes (marginal

pockets) extending into the velum (as velar canals). Conant does not dwell on phylogenetic inferences, but evidently inclines to the belief that the ancestors of the Cubomedusæ possessed a margin divided into sixteen lobes. The present position of the four sense organs indicates the site of the original margin, "which elsewhere has grown down and away from its former level, leaving the sensory clubs like floatage stranded at high-water mark." Fusion between adjacent lobes, involving the ectoderm and jelly, gave to the medusa a continuous margin and a 'velum', but, owing to the incompleteness in the fusion of the *entodermal linings* of the several lobes, the latter still retain in the adult Cubomedusa enough of their individuality to indicate their former condition. In a word, the marginal pockets of the existing Cubomedusæ are to be construed as entodermal linings of once separate lobes.

This conclusion as to the morphology of the marginal pockets derives much support from the behavior of a puzzling structure, called by Conant the marginal lamella. Unlike the true vascular lamella, which simply connects one entodermal cavity with another, the marginal lamella extends from the entoderm of the gastrovascular space to the ectoderm of the bell margin. It is a narrow strip which follows the outline of the marginal pockets, traveling in the radii of the sense organs far away from the actual edge of the bell, and surrounding the sense organs in such a way as to indicate clearly that they were once at the bell margin. The marginal lamella seems to be a functionless, rudimentary organ. Claus, whose imperfect description of the structure did not bring to light its morphological interest, as indicating the site of the ancestral bell margin, suggested that it was perhaps the vestige of a ring canal. Conant naturally is skeptical of this explanation of a lamella connecting ento- and ectoderm. The true meaning of this peculiar lamella is a

point well worth working up, more especially as it is not confined to the Cubomedusæ, but has been observed in the ephyra lobes of discophores (*Rhizostoma*).

Before leaving this subject of the general body-plan, it may be mentioned that while the probability is that the Cubomedusæ are descended from stalked ancestors *Lucernaria*-like forms, and hence that the apex of the ex-umbrella was once drawn out into a peduncle, there is in the adult Cubomedusa no trace externally or internally of this hypothetical stalked condition. Light on this very interesting point can only be expected from a study of the development.

Unlike the other Scyphomedusæ studied, the Cubomedusæ possess a nerve ring. In their study of the nervous system Claus and Conant both depended on sections, and naturally the results are not so satisfactory as those reached by the Hertwigs on the Hydromedusæ mainly with the aid of macerations. Claus describes the neuro-epithelium as consisting of alternating supporting cells and sensory cells, the inner ends of the latter becoming continuous with the nerve fibres. Conant makes it doubtful whether this is the actual condition, since he does not find the sensory cells. He offers, however, no observations on the origin of the 'nerve fibres.' Macerations will probably show the connection of these fibres with at least some of the neuro-epithelium cells.

The possession of a nerve ring has been regarded (Claus) as a point of essential similarity between the Cubomedusæ and the Craspedota. The main ring in the former group is obviously a differentiation of the subumbrellar epithelium, and Claus, therefore, interprets it as homologous with the inner Craspedote ring. In the immediate neighborhood of each sense organ there are given off from the main ring two roots which *ceasing to be superficial bands* pass through the jelly, and emerge on the outer wall

of the bell (on the floor of the sensory niche). They converge and unite, forming a superficial nerve tract which crosses the base of the sense-club. These four isolated tracts are regarded by Claus as the remnants of a once continuous exumbrellar ring, such as is found in the Hydromedusae, and which here, as in the Hydromedusae, stands in connection with the subumbrellar ring through the medium of fibres that perforate the jelly. Conant, on the other hand, regards the tracts lying across the bases of the sense organs as portions of the primitive subumbrellar ring which were shut off from the main ring, when the marginal lobes grew together. With the Hertwigs and Haeckel he thus looks on the ring as not homologous with that of the Craspedota, but as a special differentiation of the subumbrellar plexus found throughout the Scyphomedusae.

The sense organs of the Cubomedusae are 'sense-clubs' or modified tentacles. In addition to the crystalline sac, the expanded head of the club bears six eyes. Four of these are simple, but two are complex organs provided with a cellular lens and cornea, a vitreous body behind the lens, and a retina. These eyes look into the bell cavity. It is especially in reference to the structure of the retina and vitreous body of the complex eyes, that Conant's conclusions differ from those of Schewiakoff. The vitreous body Conant finds is not a homogeneous structure, but is composed of prisms of refracting substance. The retina does not show the two types of cells (sensory and pigmented) distinguished by Schewiakoff. Conant's results in this matter of the retinal structure are in some respects negative. The points still to be cleared up are as in the case of the nerve cord, such as will require the free use of macerations and surface preparations of fresh tissue.

DISTRIBUTION OF WATERPOWER IN NORTH CAROLINA.*

BY J. A. HOLMES.

The two conditions essential to the development of a waterpower of any considerable magnitude are a large and fairly constant stream of water and a suitable amount of fall within a reasonable distance. In the eastern counties of North Carolina we have numerous large streams of water, but, except along the western border of the region, as a rule they have sluggish currents and are lacking in the necessary fall. In the mountain counties the streams are small, but the fall available in many cases is sufficiently great to make possible waterpower of considerable magnitude. It is in the middle counties, however, that we find the most satisfactory combination of the two essential conditions, viz. volume of water and fall; and hence it is in these counties that we may expect the largest waterpower developments and the greatest and most substantial growth of manufacturing enterprises.

It is intended in the present paper to discuss briefly the distribution of these water powers in the State in their relation to geologic features, and the accompanying map (Plate I, will prove of service in this connection.

WATERPOWER IN THE COASTAL PLAIN REGION.

Along the western border of the coastal plain region there are a number of important waterpowers, like those at Weldon on the Roanoke, Rocky Mount on the Tar,

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and those on the Cape Fear as far east as Averagesboro. These, though they lie within the limits of this region, yet structurally do not belong to it, and can best be considered under the next heading below, in which will be discussed the waterpowers which belong rather to the border zone between the coastal plain and the Piedmont plateau regions, and which can perhaps be best designated as the fall line zone.

With the exception of the waterpowers just referred to, it may be said of the coastal plain region as a whole, that its waterpowers are of no great importance. The water supply is ample but the fall is lacking. And yet there exist at many different points in this region conditions which are favorable to the development of waterpower which, though small, have considerable local value. Until a comparatively recent date, practically all of the grist mills in this section were operated by small waterpowers, and a considerable number of these grist mills are still in operation. But such water waterpowers were confined to the smaller streams, and in many cases the development of power consisted simply in the construction of a dam across the deep, narrow channel of the stream without the existence of a natural shoal, and the amount of fall is approximately the height of the dam.

The most striking feature about the waterpower developed on the majority of these smaller streams is the slight extent to which the volume of water is effected either by the rains or dry seasons. The most widely known illustrations of this condition are Rockfish creek in Cumberland county, and Hitchcocks creek in Richmond county, both of which though small are industrially important streams. The former with a drainage basin of 280 square miles, running five cotton mills, and the latter with a drainage basin of 102 square miles running six cotton mills. The explanation of

this phenomenon is to be found in the fact that the deep, porous sands of the region serve as a sponge in soaking up the rains as they fall, turning loose this water gradually during the dry season through numerous springs.

In the case of many others of the small powers in this region, as that on Colly creek in Bladen county and others in the different eastern counties, the uniformity of the flow throughout the year is favored by the further condition that the tributaries of these streams pass through extensive swamp areas which also serve to store the water for use during dry weather.

WATERPOWERS IN THE FALL LINE ZONE.

Along the "fall line" or the fall line zone in North Carolina there are conditions favorable for the development of waterpowers of considerable magnitude on our larger streams. And since the exact position of this fall line is not clearly defined, and as the conditions favoring waterpower development extend across a considerable belt or zone where this line is crossed by the larger streams, it is better in this connection to consider together these conditions as they exist at and for a few miles on both sides of this boundary line between the coastal plain and Piedmont plateau regions.

ON THE ROANOKE RIVER.

The conditions favoring waterpower development on the Roanoke river in this zone, which at this point has a width of about 9 miles, extending up the river from Weldon, may be considered as typical of those existing other points. Waterpower developments of considerable magnitude are now in progress on the Roanoke and are being planned on the Cape Fear and Yadkin.

In portions of the coastal plain region, however, where the streams are cutting their way down across the horizontal and soft strata such as alternate beds of clay and sand, we have conditions somewhat similar to those de-

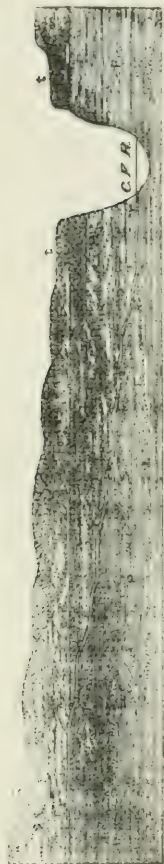


FIG. 1.—Interbedded sands and clays favoring the development of rapids in river channels.

P and P'—Finely laminated and in places cross-bedded, black laminated clay below, and bedded but cross-laminated clayey arkose above, the strata of both clay and arkose being separated by layers of sand varying in thickness from a small part of an inch to several feet. The strata marked P' above *rr* represent the same strata as P' below the *rr*. *s*—Sand hills back from the stream border. *t*—River terraces of recent loams, gravel at their base. *rr*—Surface of the stream showing that as it washes away the laminated arkose and clay, irregular rapids are produced in the stream, owing to the more rapid removal of the interbedded sand.

scribed above except that in these cases the strata, instead of being alternate layers of hard and soft rocks, are of altogether unconsolidated materials which have not yet turned to stone. Such a condition of things may be illustrated by fig. 1, which represents somewhat the conditions existing on Rockfish creek in Cumberland county.

In the lower portion of its course the waters of this creek have cut their way through the overlying sands and

loams and are now cutting through the lower interbedded sands, clays and arkose, and the still lower more finely laminated sands and greenish-black clays. Near the mouth of Rockfish these materials in its bed have been worn away to the level of the Cape Fear river

which it joins. Further back from the Cape Fear the cutting down through alternate layers of loose sand and tough clay has resulted in producing a rapid but irregular current with occasional small shoals, at several of which waterpowers have been developed by the construction of dams and factories erected.

Figure 2 may be considered as illustrating fairly well



FIG. 2.

FIG. 2.—Conditions favoring the development of cascades and rapids in stream beds crossing geologic contacts.

gt=Granite and gneiss. *sch*=Crystalline schists, in which the harder places (shaded more heavily) wear away less rapidly than the intervening softer places. The result is a series of cascades and rapids in the stream. *p*=Coastal plain deposits—gravel, sand and loam.

a generalized section across the fall line where crossed by the Roanoke river at Weldon. The crystalline schists exposed along the river bed between Gaston and Weldon (G and W of fig. 2) are much harder and more obdurate than the unconsolidated coastal plain deposits below, and even harder than the granite and gneissic rocks above it; and hence the latter rocks have been eroded to greater depths, and at the line of junction between the two (1 in fig. 2) the schists form a sort of barrier or natural dam, for many miles above which the river is deep and the current sluggish. But from this point

down to Weldon the schists vary in hardness, and are intersected by joints, seams, fissures and probably sev-

eral faults; this succession of variations giving rise to a succession of rapids and shoals, with an aggregate fall of 85 feet in a distance of 9 miles. For this distance the river flows through a deep and open gorge flanked by hills which, near Gaston and a short distance westward, are capped with unconsolidated gravels, presumably of Potomac age, and bordered by terraces of more recent age, probably post-tertiary (Columbia). In the neighborhood of Weldon and eastward the rocky hills give places to the terraces and plains of the coastal region, composed of gravels, sand, loams and clays, varying in age from Potomac at the bottom to Columbia at the top.

ON THE TAR RIVER.

On the Tar river there is but one large waterpower, that at Rocky Mount, which may be considered as being at the eastern margin of this zone and some 20 miles eastward of the western border of the coastal plain region. The Tar rises nearly 100 miles to the northwest of this point and crosses successively several granitic, schistose and slaty belts of rock, but owing to the slight elevation of this upper part of its basin above that of the coastal plain, the long period during which the rocks of this upper basin have been undergoing surface decay, and the long period during which this stream, with no great volume of water, has been slowly carving out its channel, its freedom at the present time from conditions favorable to waterpower is easily understood. At Louisburg there is a fall of several feet owing to a change in the character of the granitic rocks. At Rocky Mount it turns eastward and crosses a ledge of hard granitic rock, on the eastern slopes of which there is a natural fall of about 15 feet in the course of 100 yards. It is on the top of this granite ledge that the dam has been built which serves for the full development of this waterpower for operating the Rocky Mount cotton-mill.

ON THE NEUSE RIVER.

On the Neuse river, as on the Tar, there is rather a remarkable absence of conditions favorable the development of large waterpowers. Of the two powers worthy of mention, both lie within the granite area, one to the north and the other to the north-east of Raleigh, and are due to local changes in the character of the granitic rock.

ON THE CAPE FEAR RIVER.

The fall-line zone on the Cape Fear river may be said to begin where this river is formed by the junction of the Deep and Haw rivers, and to extend from that point to a short distance below Smileys falls, near Averasboro. In this distance of about 35 miles there is a succession of shoals beginning just above with Buckhorn falls, 9 miles below the junction of the two rivers, where there is a fall of 20 feet in a distance of one and one-half miles, while the lowest of the prominent shoals, "Smileys falls," 30 miles below the junction, has a fall of 27 feet in a distance of three and one-half miles. The total fall from the junction of the two rivers to just below Smileys falls is about 100 feet. Within 17 miles below Smileys falls, by river, there are at least three different shoals, the last of which is only 8 miles above Fayetteville; but none of them are of any importance, and they need hardly be considered in this connection.

The outlying gravels of the coastal plain deposits are to be found on the hills two miles to the west of the junction of the Haw and Deep rivers, so that all the shoals just mentioned lie within this region, and the sands and loams and gravels characteristic of the border deposits are exposed here and there in the river bluffs, though in the river channel these have been removed and the waters rush along over the upturned and irregular

eroded edges of granites and crystalline schists. Within a few miles above the junction of the Haw and Deep rivers both of these streams pass from the slates of the Piedmont plateau region to and across a narrow strip of Jura-trias sandstone, which latter is made up of materials far more easily eroded than the slates, and as might be expected there are shoals on both streams at this junction. The rivers join within this sandstone area, and for a few miles below the junction the Cape Fear is a sluggish stream.

ON THE YADKIN-PEE DEE RIVER.

On the Yadkin-Pee Dee river a condition of things exists somewhat similar to that on the Cape Fear just mentioned. The course of the Yadkin river as it crosses the slates, for some 15 miles above its junction with the Uharie, is briefly described further on. Below its junction with the Uharie the river flows for a distance of some 20 miles in a southerly course obliquely across and in places paralleling the upturned edges of the argillaceous slates. In this distance there are only two prominent shoals, but neither of great importance as compared with those at the narrows above. These are Swift Island shoal, 42 to 44½ miles above the state line, and Gunsmith shoal, 13 miles further up the river. Further down, the river flows easterly as a somewhat sluggish stream across a few miles of red sandstone rocks, similar to those crossed by the Cape Fear at the junction of its two tributary streams. It then enters the coastal plain region, near where it is joined by Little river and follows a southerly course via Cheraw, 35 miles below. Throughout this distance there is a succession of shoals due to the fact that the river crosses the upturned and irregularly eroded edges of alternate beds of slaty and granitic rocks.

The river crosses the lower limit of the fall line zone a little above Cheraw. The shoals in the river at that point and for some distance above are not large, but they are sufficient to mark the passage of the river from its characteristics in the Piedmont plateau region to its typical coastal plain condition, that of a sluggish stream.

GEOLOGIC CONDITIONS FAVORING WATERPOWER DEVELOPMENT AT THE
FALL LINE.

(1). The eastward tilting of the surface of these older crystalline rocks, and (2) the partial removal of the loose and easily eroded loams and gravels from the channel on the eastern slope of these rocks, have given this resulting descent in the river surface at the fall line, which, in the Roanoke at Weldon, aggregates 85 feet in 9 miles. (3) The variation in the character of the rock, being harder and more obdurate at certain points, and softer, more jointed, more crushed, and hence more easily eroded at the intervening areas, results in concentrating this fall of the stream at certain places; and (4) the existence of terraces along the river banks facilitates the construction of canals which still further concentrate the fall of the water. These are the more important geologic conditions that favor the development of important waterpowers on the Roanoke at the fall line in the Weldon region.

Other striking cases illustrating the conditions favoring waterpower development on streams crossing geological contacts will be found mentioned on pp. — and — of this report.

WATERPOWER IN THE SLATE BELTS.

One of the most common types of geological structure affecting waterpower development in North Carolina

and other south Atlantic states is that to be found in the great belts of slates and crystalline schists lying in the eastern part of the Piedmont plateau region. (See map). Here, as in structural type shown in fig. 3 below, layers or sheets of rocks are nearly vertical, and are composed of material varying in hardness and durability; but throughout much of this belt, and especially along its western border, the variations are less well defined and on a smaller scale, the thin, hard layers being so numerous and so generally distributed that in the streams like the Haw and Deep rivers, which cross the larger portions of these belts nearly at a right angle, there is almost a continuous series of small rapids or shoals with an aggregate fall of from 5 to 20 feet to the mile.

The possibility of waterpower development on the Haw, Deep and Yadkin, as they cross the central and most extensive of these slate belts in Alamance, Randolph, Davidson, Stanly and Montgomery counties, is greater than on any other portion of these rivers.

ON THE HAW AND DEEP RIVERS.

Both the Haw and Deep rivers rise in the granitic and gneissic area, the former to the northwest and the latter to the southwest of Greensboro, and are sufficiently large in volume to be available for small powers by the time they reach the western border of the slate belt. Throughout their course of about 50 miles across it each river is a succession of shoals or rapids, many of which have already been developed, while a number of others are capable of being developed on a considerable scale. The slates and schists of this region have a general northeasterly course, and, as a rule, dip steeply toward the northwest, so that these streams with a southeasterly course have cut their beds directly across the upturned

edges of the slates, which vary in hardness and obduracy from point to point, the harder sheets projecting upward as ledges, and the intervening softer sheets being washed out as depressions, which thus give rise to the shoals and rapids.

ON THE YADKIN RIVER.

The Yadkin river strikes the slate belt some 12 or 15 miles below the Southern railroad crossing near Salisbury, and for a distance of 20 miles below this point the geologic conditions in this slate have resulted in a succession of shoals and rapids which promise to be of great value in connection with the development of manufacturing enterprises.

Where the Yadkin river crosses the larger of these belts of slates and schists there is a greater concentration of the hard and soft material, and consequently a greater concentration of fall in the river at certain points, than is described above as occurring on Haw and Deep rivers; yet on the whole this Yadkin river section, illustrated with approximate accuracy in fig. 3, may be considered as fairly typical for sections of country where these belts of rock exist. The space between 1 and 2 in the diagram represents the "narrows" section, a distance of nearly 5 miles. The rock is eruptive in character, though an obscurely bedded conglomerate at the upper (N.W.) side. It is all hard, but not uniformly so, being harder and more obdurate at certain places, arranged at intervals, producing the narrows rapids at the upper end (just below 1) and the "little falls" and "big falls" near the lower end (just above 2). The total fall from 1 to 2 is nearly 100 feet.

Below the narrows between 2 and S.E. in fig. 3) the



FIG. 3.—Conditions favoring the development of cascades and rapids in river channels crossing belts of inclined slates and crystalline schists.

a=Argillaceous slates dipping northwest, with harder and more durable layers at intervals (as at 3). *b*=Crystalline schists, mainly of volcanic origin, obscurely schistose, more massive and obdurate in places, as where the shading is heavier. *c*=Finely laminated and uniform argillaceous slate.

rock is mainly an argillaceous slate of fairly uniform character and easily eroded by water action; and the existence of this softer material beside the belt of hard, obdurate rock which itself is not uniform, but has harder and softer belts, affords just the conditions favorable for the development of rapids and cascades in the stream that crosses both belts. As might be expected, these harder rocks (*b* in fig. 3) cross the country in a high, irregular ridge, while the surface of the region to the southeast, occupied by the slaty and sandstone rocks, is less hilly and less elevated. The Yadkin

FIG. 3.

crosses the harder ridge as a rushing torrent in a deep, narrow gorge—the “Narrows”—but as soon as it reaches the softer slaty rock (at 2 in fig. 3) the current slackens, the stream widens and flows on for several miles as a smooth and relatively sluggish current.

For several miles up-stream from the Narrows the rocks are mainly clay slates having a southwest-northeast course, and dipping steeply toward the northwest;

and so the sheets or beds of rock stand on edge and lean down-stream (S.E.). These rock beds are for the most part fairly soft and more easily washed away than other more massive and more durable layers which occur at irregular intervals, and consequently below these more massive sheets of rock are the shoals and rapids as indicated in figs. 2 and 3 above and as described further on.

WATERPOWER IN THE GRANITIC AND GNEISSIC AREAS.

The larger granitic and gneissic areas occupy the region from the western border of the slate belt just mentioned westward to the foot of the Blue Ridge, the typical Piedmont plateau section of the state.

In granitic and gneissic rock, the materials not being arranged in definite strata or layers, the exact conditions which cause the production of cascades and rapids in streams are less apparent than in the slaty and schistose rocks just described. The accompanying sketch (fig. 4) illustrates a few of the conditions favorable to the development of waterpowers in a region where these rocks prevail, as in portions of central and western North Carolina.

1. One often finds in such regions breaks, such as faults or joints in the rock, the material on one side of the break being somewhat crushed or sheared and hence easily removed. Of course the streams of water in crossing the section of country where these breaks or faults occur, and especially where the crushed or sheared side of the break is the lower side on a sloping surface, remove this lower side more rapidly than the upper and thus form a cascade from the higher to the lower level as seen at 1 in fig. 4. It is in that way that some of the beautiful falls of the southern Appalachian mountain re-

gion have been produced. Other cascades and shoals are developed under the following conditions:



FIG. 4.

FIG. 4.—Conditions favoring the development of cascades and rapids in river channels crossing areas of granitic and gneissic rock.

gr.=Granite. 1=Fault or break in the rock, the right side having moved down or the left side moved up. 2=A schistose zone in the granite resulting from the shearing or movement of the rock along a line of weakness. *gn.*=Gneiss, in which there are alternately harder and softer portions, the harder and more obdurate places being more heavily shaded (as at 4). 5=Dike of diabase or other material harder and more obdurate than the gneiss, and never producing a cascade or rapid in the stream channel.

2. In portions of the granitic area there are lines of structural weakness where, under great strain or pressure, the materials of which the rock is composed give way and are flattened out by a process known as shearing, so as to give there a rather gneissic or schistose structure, as at 2 in fig. 4. The rock in this condition is often more rapidly attacked by the weathering and eroding forces of the atmosphere, and, consequently, as the streams cross the surface of the

country where such conditions exist, they carve out their channels more rapidly, thus producing shoals or rapids, and, in extreme cases, cascades or falls.

3. Conditions somewhat similar to the above and favorable to the formation of shoals and rapids in streams are sometimes found along the line of contact between areas of granites and gneisses, as at 3 in fig. 4; and

again in gneissic areas in places the rocks are harder and more obdurate, as indicated by heavier shading at 4 in fig. 4; and in the beds of streams crossing such areas the rocks wear away irregularly, the harder portions standing out as projections while the intervening softer materials are hollowed out. In this way we have produced a succession of shoals, a few hundred yards or several miles apart; and between these are to be found the quiet reaches of the streams where the current moves along more smoothly and quietly.

4. Another structural feature in granitic and gneissic areas, and also in slaty and sandstone areas, which occasionally results in the production of the shoals and rapids, is the occurrence of dikes, where cracks in the earth's crust have been subsequently filled with various materials in a plastic and usually a molten condition and which materials have subsequently hardened. If the material of the dike is softer than that of the granitic or gneissic rock on one or both sides of it, then there will be a drop in the course of the stream from the adjoining rock of the wall down on to the softer dike surface, as is shown at 2 in fig. 4. If on the other hand the material constituting the dike is harder and more durable than the materials on each side of it, the country rock on the lower side of the dike, owing to its being softer and less durable than that composing the dike itself, will wear away more rapidly than the material of the dike, and consequently the water will drop from the dike surface on to the country rock below it, as indicated at 5 in fig. 4 above. The occurrence of the belt of eruptive rocks between the two belts of slate, as shown in fig. 3 (p. 103), may be considered as analogous to this last-mentioned case. On the Deep river near Gulf and on New Hope creek, a tributary of Haw river, are to be found illustrations of the development of waterpower being favored by the oc-

currence of diabase dikes in the Jura-trias sandstone crossing the channel of the stream.

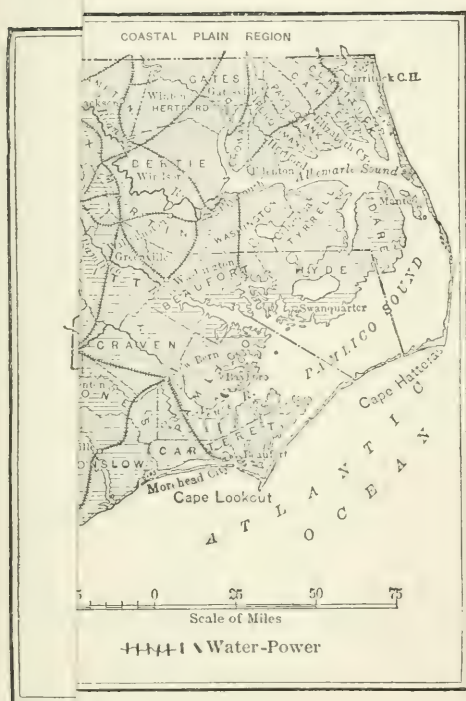
ON THE YADKIN AND CATAWBA RIVERS.

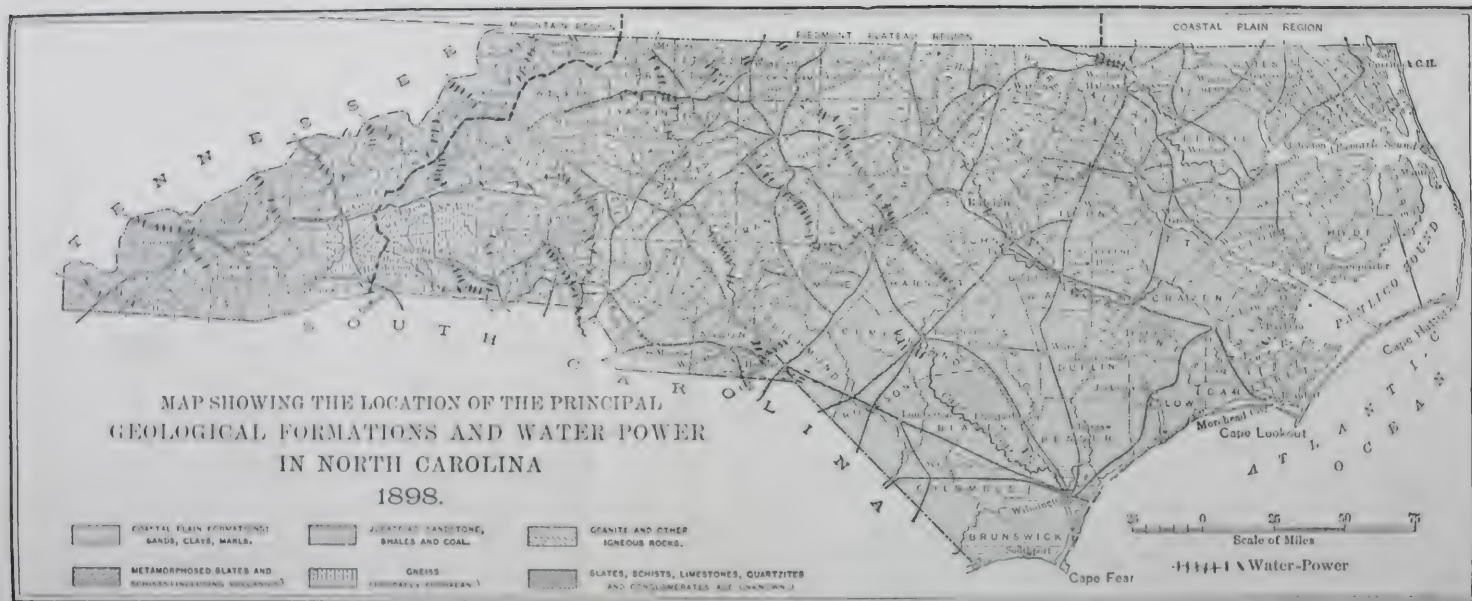
The conditions favoring the development of waterpowers in granitic and gneissic areas have been described very briefly above, and the cascades and shoals and rapids on the Yadkin and Catawba, as well as on the tributaries of the Broad, will generally be found to have their origin in local changes in the character of the rock, in one or another of the ways there suggested. All of the conditions there described are to be found illustrated at intervals in this region.

As will be seen the shoals on the upper Yadkin, which lie within the area now under consideration, are less numerous than those on the same stream in its course across the belt of slate and schist already described. And inasmuch as the changes in the character of the rock in the region of the upper Yadkin are for the most part not radical, the amount of the fall at each of the shoals is less great than in the slate belt. This fact, together with the diminishing volume of water as we ascend the stream, render the powers on the upper portions of this stream less important.

The Catawba river, which, like the Yadkin, rises along the crest and eastern slope of the Blue Ridge, flows nearly a hundred miles in a northeasterly course and then turns southward. Its course in North Carolina lies entirely within the gneissic and granitic area. From Morganton eastward for a distance of nearly 40 miles the river either parallels the general strike of the rocks or crosses it obliquely. The changes in the character of these rocks are not numerous, and the number of shoals correspondingly small, though several of them are of considerable magnitude. The river then runs in a south-

easterly and southerly direction for a distance of but little more than 25 miles; but in this distance it crosses





easterly and southerly direction for a distance of but little more than 25 miles; but in this distance it crosses the course or strike of the rocks at right angles. The changes in the character of the rocks are numerous, the rocks even being schistose and slaty in places and the stream is literally a succession of shoals, the aggregate fall being not less than 175 feet. At a point some 10 miles south of Statesville, as will be seen on the small map, the river reaches the typical granite belt of this region and flows thence southward for a distance of approximately 40 miles, where it crosses the state line into South Carolina. In this part of its course the rocks of the region are again more nearly uniform, and though there are several shoals of importance, as those at Cowans ford, Mountain Island, and Tuckaseegee, yet the number of these shoals in proportion to the distance is much smaller than in the 25-mile section next above.

ON THE TRIBUTARIES OF BROAD RIVER.

Among the tributaries of the Broad in Cleveland and Rutherford counties, the streams descend rapidly from the South Mountains along the upper border of these counties down to the general plain of the Piedmont plateau, flowing in a southerly and southeasterly direction nearly at right angles to the general strike of the rock, and in this way encountering the greatest number of changes in the character of these rocks, which results in conditions most favorable for the development of waterpower. Hence it is that we have in this region a large number of valuable waterpowers, some half dozen of which are already operating cotton-mills, while others are soon to be utilized in the same way.

CONDITIONS IN THE SLATY AND GNEISSIC AREAS COMPARED.

In any study of the streams and waterpowers of the

Piedmont plateau region it should be borne in mind that while the slaty belts present more favorable conditions for developing waterpowers, as shown in the case of the Yadkin and the other streams which cross the several belts, owing to the fact that in these belts the sheets of rock stand more on edge and vary more in hardness and durability, yet the streams which draw their supplies from the granitic and gneissic areas are more uniform in their flow for the reason that while the rainfall in the different belts is approximately the same, the soils in the granitic and gneissic areas are deeper and more porous and serve more as a sponge for storing up the surplus water of rainy seasons than does the more shallow and compact clayey soils resulting from the decay of the slates. This is one of the principal causes why the flow is less uniform in the case of the Haw and Deep rivers (see map), which lie largely in the slaty belt, than in the case of the Yadkin and Catawba, which lie almost wholly in the granitic and gneissic areas. Fortunate it is then, that these two larger rivers have their headwaters in the granitic and gneissic areas, with gravelly, porous soils; and flow across the great slate belt after they have attained their larger proportions.

WATERPOWER IN THE MOUNTAIN REGION.

A glance at the accompanying small geologic map will show that the larger part of this region is occupied by gneissic rocks. These have for the most part a characteristic northeast and southwest strike, and the irregular sheets of rock dip beneath the surface at varying but generally steep angles. The southern half of the region has along its western border an irregular belt of bedded slates, limestones, quartzites and conglomerates; and these rocks, which make up the bulk of the Great Smoky mountains, have a general north-

easterly strike and dip at steep and varying angles. Near the eastern border of the region there is another but more narrow and irregular belt of rock of a somewhat similar character, following approximately the general position of the Blue Ridge mountains.

The general physiographic features of the region are those mountains and hills with narrow valleys. It may be restated here that the rivers of this region have their sources mainly along the western slope of the Blue Ridge, and that with the exception of New river, near the northern boundary, they flow in a general northwesterly direction across the upturned edges of both the gneissic and the more recent bedded rocks. The elevation of the country is so great and the descent of the streams so rapid that the general courses of the principal rivers have been but little modified by geologic structure, though their courses lie directly across the strike of the rock; and the resulting conditions are such as to produce along the streams occasional rapids and cascades. Especially would this be the case in the western counties, where the Pigeon, the Tuckasegee, the Little Tennessee and the Hiwassee break through the Great Smoky mountains, and in doing so cross a variety of limestone, quartzite and conglomerate beds which go to make up the geologic formation of that area, but for the fact that during the long period of time that these streams have occupied their present channels, owing to the rapidity of their flow and the large quantities of abrading materials, such as sand, gravel and bowlders, carried down in their currents, the variations in the obduracy of the rocks, crossing these stream beds seldom result in cascades of large proportions, for the reason that the would-be projecting ledges of rock across the stream bed are kept down near the general level by these eroding agencies.

A number of the smaller tributary streams flow in either

a southwesterly or a northeasterly direction along the line of the strike of the rocks and thus develop the conditions favorable for waterpower, mainly where they vary their courses and cross from rock of one character to one of a different character. In the extreme northern portion of the region the tributaries of New river rise both on the western slopes of the Blue Ridge and the eastern slopes of the Iron mountains, and flow in a general northeasterly or northerly direction, sometimes following the line of the strike, and sometimes crossing the latter at sharp angles. Along New river and its tributaries are a number of shoals which can be developed into valuable waterpowers, occurring mainly at points where the streams cross the strike of the gneissic rock of the region.

In connection with the development of these waterpowers, the river gorges are so narrow and the streams so rapid that while the construction of large dams is a matter attended with no insurmountable difficulties, yet it is often difficult to find suitable space for buildings, and it has been found more advisable in a number of cases to construct small dams and to convey the water from these in open ditches or flumes along the banks of the stream to suitable points where the power may be utilized. The chief difficulty which is met in storing water on these streams is that the ponds or storage reservoirs become rapidly filled with sand, gravel and bowlders brought down in time of flood. Probably the future development of these powers will be largely in connection with electrical transmission.

GEOLOGICAL CONDITIONS AFFECTING THE FLOW OF STREAMS.

The yearly discharge of a stream depends primarily on the amount of rainfall in the region from which the stream draws its supply, but in a measure this volume, and especially the uniformity of flow, are largely in-

fluenced by the slope of the surface, the depth and porosity of the soil, and the character of the underlying rock. In connection with this study of the geologic conditions influencing the possibilities of waterpower development, it should be noted that the occurrence of lakes, swamps or marshes and poorly-drained level areas, deep and porous soils, such as the sandy and gravelly soils from 10 to 100 feet deep, which occur in the larger part of the Piedmont plateau and mountain regions of the Carolinas, the great sand hills of the southern coastal plain region, and the porous sands and gravels of the glaciated regions of the Northern states, all facilitate the uniformity of the flow of the streams in these several regions; and in some regions the jointed, fissured and crushed condition of the underlying rock exerts a favorable influence in the same direction.

NOTES ON GRASSES.

1) CONTRIBUTIONS FROM MY HERBARIUM. No. IV.

W. W. ASHE.

Since the publication of a paper on the Dichotomous Group of *Panicum* in the Eastern United States (in this Journal, vol. xv, Nov., 1898) I have found among some duplicates additional material of a plant, a single specimen of which I had at that time, but such scanty material that I did not care to base a species on it, though it

1) Issued April 20, 1899.

showed excellent specific characters. I find that I have collected the plant at two stations, both in Orange county, N. C.

PANICUM ORANGENSIS, sp. nov. Stems 12 to 24 inches long, ascending from a geniculate base, pubescent with long, soft, white, matted hairs, but more or less glabrate towards the top. Lower sheaths crowded and overlapping, pubescent with soft matted hairs; the upper distant and nearly glabrous. Leaves soft-pubescent like the sheaths, the largest 3 to 4 inches long and 3" to 5" wide, lanceolate, long taper-pointed, largest near the base of the stem; the upper much reduced and often glabrous. Ligule pilose with long hairs. Panicle long-peduncled, oblong, the very numerous, slender fascicled branches ascending; spikelets scarcely $\frac{3}{4}$ " long, obovate, apiculate, the first scale about one-third as long as the glabrous 7-nerved second and third.

Related to *Panicum lanuginosum* Ell., and separated from it by having a longer, softer pubescence and its leaves not being ciliate. Collected in June, 1898.

As the name *Panicum commelinaefolium* proposed by me (Mitchell Journ. 15, part 1; 29) for a Georgia plant has already been used by Kunth for another grass, I propose the name *Panicum Currani* for my plant; and for *Panicum Georgianum* Ashe (ibid, 36) I propose the name *Panicum Cahoonianum*, since Sprengel has made use of the nearly similar *P. Georgicum* for a different plant.

ANDROPOGON GYRANS sp. nov. Stem very slender, 18 to 24 inches high, glabrous or merely bearded at the upper joints. Basal leaves 10 to 14 inches long, 1" wide or less, glabrous, often involute and twisted, those of the stem much shorter. Sheaths glabrous. Branches very few, scarcely protruding from the closely wrapped sheaths. Spikes 2 or 4, generally 4, very slender, 6 to 12 flowered, spikelets $1\frac{1}{2}$ " long, shorter than the copious, white, basal hairs; sterile spikelets of single scale, cov-

ered with long spreading hairs, as well as its slender pedicel.

Distinguished from *A. Elliotii* and all the slender forms of that species, by the much smaller spikelets, scattered branches and narrow sheaths, which do not enlarge.

Collected by the writer in pine woods in Durham county, N. C., Oct. 1896.

ANDROPOGON MOHRII PUNGENSIS, var. nov. Less tomentose than the type. Spikes generally more numerous, 4 to 12, and shorter, enclosed in the sheaths or protruding.

Collected by the writer in grassy swamps at the head of Pungo river, Washington county, N. C., Oct. and Nov., 1898.

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SIXTEENTH YEAR—PART FIRST

1899

THE DEFINITION OF THE ELEMENT.

F. P. VENABLE.

It is with hesitation that I enter upon so speculative a discussion as the nature of the elements, and yet there are reasons why it should prove of great profit to draw the attention of this representative gathering of the chemists of America to this subject. We have nearly reached the close of the first century in which these elements have been the subject of experimental research. The ingenuity and the patient labor of an army of workers have been directed toward the solution of the many problems connected with these elementary substances, and the ultimate aim, the goal, of all their striving has been the discovery of the properties and the nature of the atom.

It is eminently fitting that, as we stand at the threshold of the new century, we glance back along the road we have already come and take some account of the progress we have made. The quicksands of mere speculation must be avoided, and yet the mental vision, the 'scientific imagination,' must be called into service in considering that which so far transcends our cruder actual vision as the incomparable atom itself. There is another reason for considering the nature of

* An address delivered as Vice President before the Chemical Section American Association for the Advancement of Science—Columbus, O., 1899.

the elements. At several times during the century a wider vision has made it necessary to recast the definition of the elements to accord with increasing knowledge. It would seem as if another such period of change were approaching. There may be need of a truer definition, and how shall this be realized or the new definition properly fitted unless the knowledge gained be summed up and appreciated?

The conception of an element among the Greek philosophers and the earlier alchemists was very different from the modern idea. This conception sprang from the theories as to the formation of the material universe. The elements were the primal forms of matter seen only combined, impure, imperfect. They were the essences or principles out of which all things were evolved. In the four-element theory, which was so widely spread among the ancients, the fire, air, earth and water were not the ordinary substances known under these names, but the pure essences bestowing upon fire and water their peculiar properties. These essences were not thought of as actual substances capable of a separate material existence, and gradually the belief that a transmutation was possible between them sprang up. Thus they themselves might be derived from some one of them, as fire or water. The Thalesian theory deriving all things from water was especially popular and was not completely overthrown until the modern era.

When, later on, the alchemists conceived of all metals as composed of sulphur and mercury it was an essence or spirit of mercury that was meant. Certain common characteristics as luster, malleability, fusibility, combustibility, etc., naturally led them to think of the metals as belonging to the same order of substances containing the same principles, the relative proportions and purity of which determined the variations in the observed properties. Thus the properties of the metals depended upon the purity of the mercury and sulphur in them, the quantities of them and their degree of fixation. The more easily a metal was oxidized on being heated, the more sulphur it contained, and this sulphur also determined its changeability. The more malleable it

was, the more mercury entered into its composition. If only something could be found which would remove the grossness from these essences, some unchanging, all-powerful essence, which, because of their search for it, gradually became known as the 'philosophers' stone,' then the baser metals might be transmuted into the noble gold when the sulphur and mercury were perfectly balanced and free from all distempers.

As has been said, these principles entering, all or some of them, into every known substance, were supposed to be not necessarily capable of individual existence themselves. This was the view held by the followers of Aristotle. With the reaction against the domination of the scholastics, other views began to be held. It was Boyle who first gave voice to these changed views in his 'Sceptical Chymist' (1661). He defined elements as "certain primitive bodies, which, not being made of any other bodies, or of one another, are the ingredients of which all those called perfectly mixed bodies are immediately compounded, and into which they are ultimately resolved." He, however, did not believe himself warranted, from the knowledge then possessed, in claiming the positive existence of such elements.

But little attention was paid to the subject by the subsequent chemists. The phlogistics were too much occupied with their theory of combustion, and none could see the bearing of this question and its importance to exact science.

Macquer, in his 'Dictionary of Chemistry' (1777), words his definition as follows: "Those bodies are called elements which are so simple that they cannot by any known means be decomposed or even altered and which also enter as principles or constituent parts, into the combination of other bodies." To this he adds: "The bodies in which this simplicity has been observed are fire, air and purest earth." In all of this may be observed the resolution of observed forms of matter into primal principles following the dream of Lucretius and the early Epicurean philosophers, a dream abandoned by the atomic school following, though largely holding to the same definition.

It was only when chemists began to realize that mere observation of properties, chiefly physical, was not sufficient that the subject began to clear up and lose its vagueness. Black proved that certain substances were possessed of a constant and definite composition and fixed properties, unalterable and hence simple bodies or elements. Lavoisier finally cleared the way for the work of the nineteenth century by his definition that "an element is a substance from which no simpler body has yet been obtained; a body in which no change causes a diminution of weight. Every substance is to be regarded as an element until it is proved to be otherwise." With this clear definition to build upon, a rational system of chemistry became, for the first time, a possibility.

Thus the elements were recognized as simple bodies because there were no simpler. They were not complex or compound. This distinction was clearly drawn between bodies simple and bodies compound, and the name simple body has been frequently used as a synonym for element through a large part of this century. Naturally the question of simplicity was first settled by an appeal to that great arbiter of chemical questions, the balance. And, quite as naturally, many blunders were made and the list of bodies erroneously supposed to be simple was very large. All whose weight could not be reduced were considered elementary. When, however, from such a body, something of lesser weight could be produced, its supposed simplicity was, of course, disproved.

This test for the elemental character has been clung to persistently, and is perhaps still taught, although it was long ago recognized that many of the elements existed in different forms, a phenomenon to which Berzelius gave the name *allotropism*. One only of these could be the simplest, and the others could be reduced to this one and rendered specifically lighter. With the discovery of this relation it should have been quite apparent that the old definition would no longer hold good. But many years passed before chemists were made to feel that a new definition was necessary, and adapted one to the newer knowledge.

The insight into what Lucretius would call 'the nature of things' was becoming clearer; the mental grasp upon these elusive atoms about which the old Epicurean reasoned so shrewdly was becoming firmer. Through what one must regard as the veil interposed by the earlier idea of the element, the chemist began to grope after the constituent particle or atom. It must be borne in mind that the definition of the element was largely formulated before the resuscitation of the atomic theory by Dalton, and the mental picture of the one has perhaps retarded the clearing up of the ideas concerning the other. From the atomic point of view the element was next defined as one in which the molecules or divisible particles were made up of similar indivisible particles. This afforded an easy explanation of allotropism as a change in the number of atoms in a molecule. As Remsen says: "An element is a substance made up of atoms of the same kind; a compound is a substance made up of atoms of unlike kind."

Laying aside, then, all vaguely formulated ideas of essences, or principles, or simple bodies, or elemental forms, we found our present building upon the conception of the ultimate particle, be this molecule or atom.

As to this atom some clear conception is needed, and here we come to the *crux* of the modern theories. The chemist regards this atom as a particle of matter and is unwilling to accept the theory of Boscovich that is infinitely small, and hence a mathematical point, nor can he admit that it is merely a resisting point, and hence that all matter is but a system of forces. And yet it seems as though some authorities would lead up to such a conclusion.

While we need not consider these atoms as mere centers of forces, we are compelled to study them by the operation of forces upon them. What are called their properties have been studied and recorded with great care. These properties are evinced in the action of the forces upon matter, and the exhibition of force without matter cannot be admitted. This study of the properties has been the especial occupation of the century now closing, and so the elemental atom has come to be regarded as a collection of properties. As Patterson-Muir puts it (Alchemical Essence and the Chemical

Elements, p. 31 : "The name copper is used to distinguish a certain group of properties, that we always find associated together, from other groups of associated properties, and if we do not find the group of properties connoted by the term copper we do not find copper."

These properties are exhibited by the action of a small group of forces. Perhaps we do not know all of the forces: certain it is that we do not accurately know all of the properties, but, to quote Patterson-Muir again: "The discovery of new properties always associated with a group of properties we call copper would not invalidate the statement that copper is always copper."

The properties of an atom are either primary, inherent and as unchanging as the atom itself, or they are secondary and dependent upon the influence of the other atoms, or varying with the change of conditions. To the first class belong such properties as the atomic weight, atomic heat, specific gravity, etc.; to the second, chemical affinity, valence, etc. In all the study of the atom the distinction between these should be carefully maintained in order that there may be clear thinking.

There is no field of mental activity requiring more faith than that of the chemist. He is dealing with the 'evidences of things unseen.' He must not be content with the mere gathering of facts, but divine what he can of their deeper meaning. Few chemists have had such insight as Graham into the significance of even the simplest changes. He was not content with mere surface observation. Even the commonest phenomena were to him full of meaning as to the atoms and their 'eternal motion.' Thorpe (*Essays in Historical Chemistry*, p. 219) has drawn afresh the attention of the chemists to the thoughtful words of this great thinker. His mind was filled with the fascinating dream of the unity of matter. "In all his work," says Adam Smith, "we find him steadily thinking on the ultimate composition of bodies. He searches after it in following the molecules of gases when diffusing; these he watches as they flow into a vacuum or into other gases, and observes carefully as they pass through

tubes, noting the effect of weight, of composition, upon them in transpiration. He follows them as they enter into liquids and pass out, and as they are absorbed or dissolved by colloid bodies; he attentively inquires if they are absorbed by metals in a similar manner, and finds remotest analogies which, by their boldness, compel one to stop reading and to think if they really be possible."

In his paper entitled 'Speculative Ideas respecting the Constitution of Matter,' published in the Proceedings of the Royal Society in 1863, which Thorpe calls his 'Confession of Faith,' he tells of his conception that these supposed elements of ours may possess one and the same ultimate or atomic molecule existing in different conditions of movement.

It is not possible for me, in the limits of this address, to array before you all of the various evidence which leads to the belief that our so-called elementary atoms are after all but compounds of an intimate, peculiar nature whose dissociation we have as yet been unable to accomplish. When properly marshalled, it gives a very staggering blow to the old faith. Thorpe speaks of the "old metaphysical quibble concerning the divisibility or indivisibility of the atom." To Graham "the atom meant something which is not divided, not something which cannot be divided." The original indivisible atom may be something far down in the make-up of the molecule.

How shall the question as to the composite nature of the elements be approached? The problem has been attacked from the experimental side several times during the last half century, but the work seems to have been carried on after a desultory fashion and was soon dropped, as if the workers were convinced of its uselessness. The results, being negative, simply serve to show that no method was hit upon for decomposing the elements upon which the experiments were performed. Thus, for instance, Despretz performed a number of experiments to combat Dumas' views as to the composite nature of the elements. Despretz made use of the well-known laboratory methods for the separation and purification of substances. Such were distillation, electrolysis, fractional

precipitation, etc. Such work was quite inadequate to settle the question, as Dumas had pointed out that unusual methods must be used, or, he might have added, the old methods carried out to an unusual or exhaustive extent. Certainly, if a moderate application of the usual methods was sufficient for this decomposition, evidences of it would have been obtained long ago by the host of careful workers who have occupied themselves over these substances. Crookes has busied himself with the method of fractional precipitation (though not with special view to the testing of this question), and applied it most patiently and exhaustively to such substances as the rare earths, without obtaining results from which anything conclusive could be drawn. Victor Meyer seems to have believed that the decomposition could be effected by high temperatures, and was very hopeful of experiments which he had planned before his untimely death. Others have spasmodically given a little time to the problem, but no one has thought highly enough of it to attack it with all of his energy.

Let us stop a moment and ask ourselves what would be attained if any one should succeed in decomposing an element by one of the usual methods. Has not this been done repeatedly in the past and merely served to add to the list of the elements? Didymium has been made to yield praseo- and neodymium. That which was first called yttrium has been divided into erbium, terbium and ytterbium, and according to Crookes may possibly be still further decomposed. But these and similar decompositions are not generally accepted as offering any evidence that elements can be decomposed. It is merely the discovery of one or more new substances which have remained hidden in constant association with known bodies which were supposed to be simple. It would be necessary to prove that a single individual element had, by the process adopted, been actually decomposed and not some pre-existing impurity discovered. This, of course, would be exceedingly difficult, and all such attempts as those mentioned can have little bearing upon the general question, and can hold out slight hope of reward beyond the fame springing from the discovery of a new element.

Successful decomposition should mean much more. It should mean the discovery of a method which will decompose not one, but many or indeed, all of the elements, and the decomposition of these must not yield a larger number of supposedly simple bodies, but a small group of one or two or three which are common constituents of all. It is quite idle to venture upon any prediction whether such a method will ever be discovered. Setting aside, then, the direct experimental proof of the composite nature of the elements as unattainable at present, let us next examine the indirect evidence. It would seem wisest for the present to introduce under that heading the spectroscopic work of Lockyer. The results, while highly interesting, are too indefinite as yet to speak of as having a direct bearing. Yet a careful study of the spectra of the elements leads us to a strong suspicion that the less plausible assumption is the one that the particles which give rise to such varied vibrations are simple and unitary in nature. Lockyer's most recent work, following up the line of his 'Working Hypothesis' of twenty years ago, is very suggestive and may lead to important results (*Chemistry of the Hottest Stars*, Roy. Soc. Proc., LXI., 148; *On the Order of Appearance of Chemical Substances at Different Temperatures*, *Chem. News*, 79, 145). Still too much must be assumed yet for such work to be very conclusive. He writes of 'proto-magnesium and proto-calcium,' and Pickering discusses a 'new hydrogen,' all with an assurance and confidence which proves at least how deeply these changes in the spectra have impressed some of those who have most carefully studied them.

But a more important method of indirectly testing the question is through a comparison of the properties of the atoms. Such a comparison has been made as to the atomic weights. In other words, the idea of the composite nature of the elements followed very close upon the adoption of a stricter definition of them as simple bodies. Dalton, Prout, Döbereiner, Dumas, Cooke and many others have aided in developing the idea, sometimes faultily and harmfully, at other times helpfully. Some fell into the common error of going too far, but all were struck by the fact that

when these combining numbers, or atomic weights, were compared strange and interesting symmetries appeared. The times were not ripe for an explanation of their meaning, and such crude assumptions as that of Prout, that the elements were composed of hydrogen, or that of Low, that they were made up of carbon and hydrogen, were too baseless to command much genuine support or to withstand much careful analysis. The important feature of agreement between such theories was the belief that the elements were composite and had one or more common constituents.

From the comparison of one property, the atomic weights, the next step was to the comparison of all the properties. This comparison is brought out clearest and best for us in the Periodic System. Here all the properties are very carefully tabulated for us. The study of the system leads indisputably to the conviction that this is not an arbitrary, but a natural arrangement, exceedingly simple in its groundwork, but embodying most fascinating symmetries, which hint of great underlying laws. He who looks upon it as a mere table of atomic weights has lost its meaning. It tells, with no uncertain note, of the kinship of the elements and leads to a search after the secret of their interdependence and of their common factor or factors. There is so much which is made clearer if we assume a composite nature for the elements that many do not hesitate to make the assumption.

Still another indirect method of approaching that problem is by analogy with bodies whose nature and composition are known. A very striking symmetry is observed between the hydrocarbons, and these in the form of compound radicals show a strong resemblance to certain of the elements. This analogy need not be dwelt upon here. It has been recognized for a long time and tables of hydrocarbons have been constructed after the manner of the Periodic System. Now these bodies are simply built up of carbon and hydrogen in varying proportions, and in any one homologous series the increments are regular. We know that they are composite and that they have but two common factors, carbon and hydrogen.

Again, the fact that certain groups of associated atoms behave as one element and closely resemble known elements may be taken as a clue to the nature of the elements. Thus carbon and nitrogen, in the form of cyanogen, behave very much like the halogens; and nitrogen and hydrogen in the form of ammonia so closely resemble the group of elements known as the alkalies that this "volatile alkali" was classed with them before the era of our elements and the analogy lead to a vain search for an "alkalizing principle" and later to an equally futile pursuit of the metal ammonium.

A further clue to this nature is afforded in the remarkable changes of properties which can be brought about in some elements by ordinary means, and one might mention the equally remarkable veiling of properties induced by the combining of two or more atoms. Thus copper exists in a cuprous and a cupric condition, and the change from one to the other can be readily brought about. And this is true of many other elements.

This has doubtless been a tedious enumeration to you of well-known facts and arguments, but it has been necessary, for I wish to lead you to the summing-up of these arguments and to induce you to draw boldly the necessary deductions. It is high time for chemists to formulate their opinions in this matter. It would seem as if we were shut up to one or two conclusions. Either these imagined simple bodies are after all compounds, built up of two or more common constituents, or they are but varying forms of one and the same kind of matter subjected to different influences and conditions. The supposition that they are distinct and unrelated simple bodies is, of course, a third alternative, but to my mind this is no longer tenable.

The second hypothesis is the one put forth by Graham. It was his cherished vision of the gaseous particles about which he thought so deeply, and in many ways so truly. Thorpe has written of this as follows (*loc. cit.* 222):

"He conceives that the various kinds of matter, now recognized as different elementary substances, may possess one and the same ultimate or atomic molecule existing in different conditions of movement. Graham traces the harmony

this hypothesis of the essential unity of matter with the equal action of gravity upon all bodies. He recognizes that the numerous and varying properties of the solid and liquid, no less than the few grand and simple features of the gas, may all be dependent upon atomic and molecular mobility. Let us imagine, he says, one kind of substance only to exist—ponderable matter: and, further, that matter is divisible into ultimate atoms, uniform in size and weight. We shall have one substance and a common atom. With the atom at rest the uniformity of matter would be perfect. But the atom possesses always more or less motion, due, it must be assumed, to a primordial impulse. This motion gives rise to volume. The more rapid the movement, the greater the space occupied by the atom, somewhat as the orbit of a planet widens with the degree of projectile velocity. Matter is thus made to differ only in being lighter or denser matter. The specific motion of an atom being inalienable, light matter is no longer convertible into heavy matter. In short, matter of different density forms different substances—different inconvertible elements, as they have been considered."

The hypothesis that the elements are built up of two or more common constituents has a larger number of supporters and would seem more plausible. Some have supposed one such primal element by the condensation or polymerization of which the others were formed. Thus we have the hydrogen theory of Prout, modified to the one-half atom by Dumas, and finally by Zängerle to the one-thousandth hydrogen atom. The suggestion of Crookes as to the genesis of the elements from the hypothetical *protyle*, under the influence of electricity, may also be mentioned here.

Others have adopted the supposition of two elements, Reynolds making one of these an element with a negative atomic weight, whatever that may mean. Low and others have fixed upon carbon and hydrogen as the two elements.

There are many practical difficulties in the way of these suppositions; the lack of uniformity in the differences between the atomic weights, the sudden change of electro-chemical character, and the impossibility, so far, of discovering

any law underlying the gradation in the properties of the elements with the increase of atomic weights, are some of the difficulties. In comparing these two hypotheses that of Graham seems to me very improbable. I have thought of valence as dependent upon the character of the motion of the atom, but cannot well conceive of a similar dependence of atomic weight and all the other properties. There remains, then, the hypotheses of primal elements by the combination of which our elements have been formed. These molecules are probably distinguished from the ordinary molecules by the actual contact and absolute union of the component atoms without the intervention of ether.

Since these elemental molecules cannot as yet be divided, we may retain the name atom for them, but the idea of simplicity and homogeneity no longer belongs to them. The definition of an element as a body made up of similar atoms is equally lacking in fidelity to latest thought and belief, but chemists would scarcely consent to change it, and, indeed, it may well be retained provided the modified meaning is given to the word atom. But, after all, an element is best defined by means of its properties. It is by close study of these that we decide upon its elemental nature, and through them it is tested. Complete reliance can no longer be placed upon the balance and the supposed atomic weight.

All elements are acted upon by gravity and chemical force and other physical forces, but within the last few years certain gaseous elements have been discovered which are not influenced by chemical force or affinity. According to some (Piccini, *Zeits. An. Chem.* XIX, 295) this necessitates a division of the elements into two classes. Manifestly, since it is chiefly by the action of chemical force that we study the elements, the absence of such action cuts us off from our chief means of finding out anything about them, and it is equally clear that bodies so diverse cannot well be classified together. If all attempts at bringing about the chemical union of these gaseous elements with other bodies fail, I believe that we should insist upon the existence of two classes of elements and keep them distinct in all comparisons.

Of course, we are quite at a loss to say just what chemical force is, but it is believed to be determined by the electrical condition of the atom. Thus we have the elements which show the action of chemical affinity varying from strongly electro-positive to strongly negative. This electrical charge of the atom seems to be a primitive, inherent property, and so beyond our control or power to change. At least no change of the kind has ever been recognized and recorded. Sodium remains positive and chlorine negative in spite of all that may be done to them. We can, by uniting the two temporarily, cloak and neutralize their opposite natures, but the original condition returns on their release.

Is it not fair to assume that argon, helium and their companion gases, having no affinity, are without electrical charge—atoms from which the electrical charge has been withdrawn; the deadest forms of inanimate matter? Were they thus without electro-chemical properties and affinity from the beginning, or did they start out as ordinary atoms (if I may so call them), and somehow, somewhere lose these properties, and with them the power of entering into union of any kind, even of forming molecules, doomed to unending single existence? Can these be changed atoms of some of our well-known elements, a step nearer to the primal elements and with the electrical charge lost? Is it possible for us to bring about these changes? May we not unwittingly have done so at some time or other in the past? Is it possible to restore the electrical charge to such atoms, and so to place them once more on a footing of equality with elements of the conventional type? These and many other questions surge through the mind as one thinks of these wonderful gases. Perhaps the coming century will unfold the answers.

THE NATURE OF VALENCE.

BY F. P. VENABLE.¹

The term "valence" is variously defined as the "combining capacity," or "capacity of saturation," "quantitative combining power," or "chemical value of the atom." It is well known that the introduction of this idea into chemistry was due to the development of the type theory, a system which had at first purely empirical basis. Sixty years ago there was still some hesitation as to the acceptance of the atomic theory or the need for such a theory. Much use was made of the term equivalent, which had been Wollaston's expedient for avoiding the difficulties arising from the full adoption of the theory of atoms.

Wollaston had been himself very far from consistent in the use of the term. The numbers called by him 'equivalent weights' were not infrequently atomic and molecular weights and fully as hypothetical as the so-called atomic weights of Dalton. In the later use of the term it signified solely the numbers obtained by analysis without the introduction of any theoretical considerations. Thus, on analyzing ammonia, the ratio



is gotten, and therefore the equivalent of nitrogen is 4.6. Strange to say the equivalent given by Wollaston corresponds with the present atomic weight, whereas the atomic weight given by Dalton corresponds with what would be the equivalent.

It is manifest that the idea of equivalents needed something more than the simple theory of atoms to make it clear and tenable. It embodied two distinct conceptions and if we hold to an atomic theory we must introduce a further explanatory theory of the saturation capacity of these atoms. This

¹ Address, as chairman, delivered before the North Carolina Section.

is the theory of valence or quantivalence or atomicity, and without it the equivalents are purely empirical, and it is most difficult if not impossible to clear up the confusion connected with their use.

Returning now to the derivation of this idea of valence from the type theory, according to Wurtz¹ the conception of valence was introduced into the science in three steps. First there was the discovery of polyatomic compounds. This term was first used by Berzelius in 1827², he applying it to such elements as chlorine or fluorine where he thought several atoms of these elements united with a single atom of another element. The term was later applied by Graham, Williamson, and others to compounds.

The second step was the reference of this polyatomicity to what was called the state of saturation of the radicals contained in these compounds. This was largely through the work of Williamson and Gerhardt.

Thirdly, this conception of saturation was extended to the elements themselves. This was chiefly due to the work of Frankland upon the organo-metallic compounds. And so valence has come to refer to the number of atoms with which a single atom of any element will combine.

This conception has then been one of slow growth, gradually incorporating itself into the science as the necessity arose of devising a suitable explanation for accumulated observations. It was a logical outcome of and was evolved from knowledge acquired step by step. It was no mere speculation or hypothesis, such as that of Prout, evolved by the fancy or imagination of one man and suddenly appearing with scarcely a claim to foundation upon observed fact.

This conception enters into the chemical theory of to-day almost as fundamentally as the atomic theory itself. Its application is of every-day occurrence and of the most varied character, and yet chemists admit that the nature of valence is one of their chief puzzles and they have advanced but little towards its solution during the past half century. It is quite

¹ *Histoire des doctrines chimiques*, p. 69.

² *Jsb. d. Chem.*, 7, 89.

possible that the ideas to be advanced in the further discussion of this subject in this paper will meet with opposition. Certainly they should be fully and freely discussed if they are worthy of it. I believe that they form a step toward the clearing up of the mystery of valence.

It is necessary, however, first to trace somewhat further the development of the original conception. One of its earliest and most important applications was to the study of the constitution of the compounds of carbon. Here Kekulé assumed for carbon a constant valence of four, and this idea is still dominant in theories relating to the constitution of these bodies. It was quite natural then that the first belief should have been in a constant valence. It was speedily found, however, that in certain cases, as in the compounds of nitrogen and phosphorus, this belief was scarcely tenable. There were efforts at making it hold good, as, for instance, a distinction was drawn between atomic and molecular compounds, but all of these suggestions have been proved unsatisfactory.

We unquestionably have to account for the existence of a compound with three atoms and another with five atoms in the cases of nitrogen and phosphorus and there are many similar anomalies. Here the valence seems to vary toward one and the same element. Cases might be multiplied to show also that it varies often towards different elements. Thus it frequently happens that the valence of an element towards hydrogen seems to be quite different from that exhibited toward oxygen. For a long time there was much straining to consider the valence of an element always the same but this effort is, in large measure, abandoned now as unavailing and chemists admit that valence is not constant but variable and may even vary towards one and the same element.

The doctrine of valence has had much added to it about bonds, affinities, and linkage, the necessity for which one may well question. Certainly the misuse of the word affinity, seeing its other and greater use, should be earnestly discountenanced. I am inclined to think that the other terms bring in false and misleading ideas which should be carefully guarded

against. At any rate all hypothetical talk about strong bonds, and weak bonds, double bonds and triple is to be avoided.

If then valence varies, can it be an inherent property of the unchanging atoms? Experiments have shown that it varies with the nature of the combining element, that it varies with the temperature and with other conditions. It is not dependent upon the atomic weight in the same sense as other properties are dependent upon it. Thus in the same group the valence remains the same whether the atoms weigh nine times as much as hydrogen or two hundred times as much.

We seem shut up to the conclusion that valence is not one of the primitive inherent properties of the atom but is relative. It is rather to be regarded as the resultant of the mutual influence of the atoms of the combining elements. The clear grasping of this idea is an important step forward. Unfortunately the distinction is not always made nor consistently adhered to.

It may not be amiss to cite here the utterance of Lothar Meyer in regard to the question of a constant or variable valence.¹

“Since the aim of all scientific investigation is to exhibit the most variable phenomena as dependent upon certain active invariable factors taking part in them and in such a manner that each phenomenon appears to be the necessary result of the properties and reciprocal action of these factors, then it is clear that chemical investigation would be considerably advanced were it possible to prove that the composition of chemical compounds is essentially determined by the valency of the atoms and the external conditions under which these atoms react upon one another. The first necessary step in this direction has been made in the attempt to explain the regularities observed in the composition of chemical compounds, by the assumption of a constant power of saturation or an invariable valency of the atom. The opposite and equally hypothetical assumption that the valency is variable leads to no advancement.

“The first step towards progress in this matter would be

¹Modern Theories of Chemistry, Eng. Trans., p. 303.

made if some hypothesis as to the cause of this variability were proposed. This difference between the two attitudes has seldom been properly realized. While some chemists, accepting the constant valency of atoms, have attempted to deduce the varying atomic linking from one distinct point of view, others have considered it sufficient to have assigned to the atom of a particular element in one compound one valency, and in another compound a different valency, according as this or that value appeared the most suitable, and thus to have given a so-called explanation of the composition of the compounds in question. In this way the fact has been overlooked, that an arbitrary interpretation carried out by means of chosen hypotheses, cannot be regarded as an attempt at a scientific explanation, but is nothing more than an expression of our ignorance of the causal connection of the phenomena. An explanation would require that the different valencies assigned to one and the same element in different compounds, should be traced to a different cause. If, for instance, it is stated that carbon in carbon dioxide possesses double the valency which it possesses in carbon monoxide, such a statement is no explanation of the fact that an atom of carbon in the former compound is combined with twice as much oxygen as in the latter, for such a statement is merely a paraphrase which hides its incompetency by assuming the form of an explanation. Although this may be perceived without further remark, still it has frequently occurred during the past few years that similar paraphrases have not only been proposed but also accepted as real explanations of such phenomena. Just as it was formerly supposed that the assumption of a vital force dispensed with a complete investigation of the phenomena of animal life, so many chemists have of late thought that they possessed in 'variable valency,' a means of explaining the varying stoichiometric relationships which would satisfy all claims. Such deceptions can only retard the advance of the science, since they prevent an earnest and thorough investigation of the question, whether each atom is endowed with a property determining and limiting the number of atoms with which it can combine, dependent upon the intrinsic na-

ture of the atom and like it invariable ; or whether this ability is variable and with it the nature of the atom itself."

It is not strange that this line of reasoning should lead Lothar Meyer to doubt the unvarying nature of the atom itself, and thus losing his grasp upon one invariable to make sure of another. He says: "It is by no means impossible that the magnitudes which we now style atoms, may be variable in their nature."

It will be an unfortunate day for chemists when the belief in the unchanging atom is given up. Chaos will indeed enter into all of our theories when this, the foundation rock, is left at the mercy of every shifting tide of opinion and can be shaken by all manner of unfounded hypotheses.

The case cannot be so hopeless as to necessitate calling to our aid so dangerous a doctrine. Before turning to such an expedient let us first make all possible use of our atomic theory as it stands. The extension of this theory teaches that the atoms are endowed with motion and this motion probably varies in velocity and phases with the different elements. So too when the atoms unite the resulting molecule has a certain motion peculiar to it while the atoms composing it have an intra-molecular motion in which their original motions are probably modified by their influence upon one another. It is quite manifest then that a molecule, in order to exist, must maintain a certain equilibrium and harmony between these various motions, and that there can be all degrees of equilibrium from the very stable to that which may be upset by the least disturbing influence from without.

It seems to me that herein we have a full and satisfactory means of explaining the various problems connected with the conception of valence. The question as to whether the atoms of two elements will unite is decided by affinity, which is in some way connected with the electrical condition of these atoms. There is no apparent connection between this and valence. The number of atoms which enter into combination forming one molecule is purely a matter of equilibrium and is dependent upon the motion of those atoms. Thus a phosphorus atom unites with chlorine atoms because of a certain affin-

ity between them. The number of chlorine atoms with which it will unite depends upon the possibility of harmonizing the respective motions. As the temperature may affect these motions and also impart a more rapid molecular motion, it is evident that the harmony, or equilibrium, will depend upon the temperature and that a temperature may be reached at which no harmony is possible and hence no compound can be formed. The phosphorus atom mentioned can, as we know, form a stable molecule with five atoms of chlorine. On increasing the temperature this becomes unstable and only three atoms can be retained. Neither with four atoms nor with two is there harmony of motion. A sufficiently high temperature may prevent any harmony of motion whatever being attained and hence union may become impossible.

As to other influences than those of temperature, we can see that the equilibrium between the atom of phosphorus and the five atoms of chlorine may be upset by such a molecule coming within the influence, electrical or vibratory, of a molecule of water. The atoms must rearrange themselves for a new state of equilibrium and so an atom of oxygen takes the place of two atoms of chlorine, giving again a condition of harmony. In other cases the motion of the molecule of water may be of such a character as to directly harmonize with that of the original molecule and so to enter into equilibrium with it, a definite number of such molecules of water affording a condition of maximum stability. This we call water of crystallization. Such molecules would be more or less easily separated by an increase of temperature and where several molecules of water were attached the highest temperature would be necessary for freeing the original molecule from the last water molecule.

A carbon atom finds its most perfect state of equilibrium where four atoms of hydrogen or their equivalent move in harmony with it. But there is a second state of equilibrium where only half that number of atoms are moving with it. This state does not seem to be a possibility where there are hydrogen atoms but is readily possible where the equivalent number of oxygen atoms is concerned. Such a molecule, how-

ever, is always in a condition to take up additional atoms until its highest equilibrium is reached and in doing this it proceeds by the regular steps needed for bringing about a harmony of motion. A molecule in a lower state of equilibrium we have become accustomed to call unsaturated, calling that one saturated which is in its highest state of equilibrium. The further application of this hypothesis is easily made and need not be dwelt upon here. It will be helpful in many ways.

This theory of valence makes it clear why it should vary toward the same element under different conditions. It is also clear that it might vary towards different elements as these are very possibly possessed of different motions. It is further evident that it is in accord with the conclusion that valence is not an inherent property of the individual atom but is the resultant of the influence upon each other of the combining atoms.

Only one point remains to be considered: Why do the elements of the same group have practically the same valence? The nearest answer to this, and it seems satisfactory, is that they are all possessed of the same phase or kind of motion. In other words the natural division into periods gives us seven or eight more or less different phases. These are, in large measure, independent of the atomic weight. And so the elements in any given group have the same tendency towards similar states of equilibrium in forming compounds with any other element, as hydrogen or oxygen. Some elements, as copper, mercury, tin, etc., are peculiar in that they may change their phase of motion under certain influences, acting then as if they belonged to different groups and entering into totally different states of equilibrium in forming their compounds.

Lastly it is possible for a combination of atoms of different elements, as NH^1 or CN , to have such molecular and intramolecular motion that, although not in a state of equilibrium themselves, they are capable of entering into such states just as the single atoms of elements do, having apparently similar valence.

I might develop this theory much further but it is unnecessary now. Enough has been said to show that such an appli-

cation of the atomic theory is most highly important as a step towards the clearing up of the problems springing from the conception of valence and from the periodic system.

Note.—Since certain points in this paper require treatment at greater length than was practicable in an address, it will be followed by a second paper elaborating such portions.

THE NATURE OF VALENCE.

[SECOND PAPER.]

As the preceding paper upon this subject was in the form of an address before one of the local sections of the society, the hypothesis as to the cause of valence there suggested was given in outline only and could not be enlarged upon as far as may have been necessary. In the present paper it is proposed to elaborate certain points and to test, as far as possible, the reasonable nature of the hypothesis.

While the whole subject of valence has been much confused, and the use of some of the terms connected with it unfortunate, no part of it has given greater trouble than its variability. This is the very point, however, which affords the best clew to its solution and should therefore be treated at some length.

The most instructive cases of varying valence are those where the variation is shown towards the same element, as in the compounds PCl_3 and PCl_5 , FeCl_2 and FeCl_3 , Hg_2O and HgO , CO and CO_2 , and many other similar compounds. There are two possible views regarding these. Either the valence varies or the valence remains the same and the differences are explained by some such assumption as that of a state of saturation of the atom and of various unsaturated states.

The terms 'saturated' and 'unsaturated' present a number of anomalies as commonly used. In the first place the term saturated is not always used for that condition of the atom in which it is united with the largest number of other atoms. Thus, ferrous oxide (FeO) is called unsaturated, and ferric oxide (Fe_2O_3) saturated, though there is a larger proportion still of oxygen in ferric acid and the ferrates. The same is true of the three series of manganese and chromium compounds.

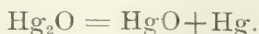
Again the term saturated does not carry with it any definite relation to the stability of the compound. Sometimes the compound called unsaturated, and containing the least number of atoms is the most stable, sometimes that with the largest number. Phosphorus trichloride is more stable than the pentachloride, but the pentoxide is more stable than the trioxide. The most stable of the manganese compounds are the so-called unsaturated manganous salts; in the case of chromium it would appear to be the chromic salts. In the case of carbon the saturated compounds are the most stable. It is manifest that these two terms cannot cover all cases of combination for a number of elements. It would seem wiser and simpler then to speak of the valence directly when discussing the elements, as bivalent carbon or quadrivalent carbon; bivalent or trivalent iron, etc. In the case of carbon compounds the terms have acquired a somewhat different meaning and are too thoroughly incorporated in the literature for a change to be suggested. Saturated here means a compound which can take on no further atoms by addition, while an unsaturated compound can have such atoms added.

Certain cases of change of valence, as in cuprous and cupric compounds, mercurous and mercuric, ferrous and ferric, etc., have been looked upon as presenting some peculiar relationships. Such cases are spoken of by some as if they occurred among positive elements only. It is not clear how any distinction can be drawn between these and the classes phosphorus and phosphoric, sulphurous and sulphuric, ni-

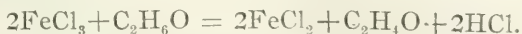
trous and nitric, chlorous and chloric, etc. A possible distinction might be made that the more negative the element the greater the number of changes of valence; the more positive the element the less variation in valence is observed. This would be an approximation only.

So great is the difference caused by this variation in the valence that some have even thought it best to arrange what have been called the lower and higher stages under different groups. Thus Mendeléeff placed cuprous copper in Group I, and cupric copper in Group VIII; aurous gold in Group I and auric gold in Group VIII. Such an arrangement would, however, greatly confuse the periodic system. Mercury, thallium, chromium, manganese, phosphorus, arsenic, sulphur, selenium, and others would have to be similarly provided for. It is better to retain them in the positions to which their atomic weights would assign them and to study them more thoroughly, so that we may understand why certain elements, as copper, gold, and mercury show this peculiarity while others closely akin to them, as silver, zinc, and cadmium, do not. In studying the nature of valence from the standpoint of its variability, the means by which these variations can be brought about must have an important bearing upon the subject. There are a number of these agencies.

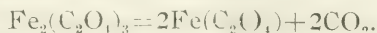
Light.—It is a matter of common observation that light can bring about physical, and the most varied chemical, transformations. In some cases it is apparent that the transformation is one from a higher to a lower valence or *vice versa*. Thus, certain mercurous compounds can be changed to mercuric.



An alcoholic solution of ferric chloride is changed by light to ferrous chloride.

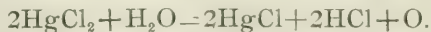


Ferric oxalate under the influence of light gives off carbon dioxide and becomes ferrous oxalate.



An alcoholic solution of cupric chloride becomes cuprous

chloride. Mercuric chloride in aqueous solution is slowly changed to mercurous when exposed to the light.



Gold chloride (AuCl_3), in contact with organic substances, when exposed to light, is changed first to aurous chloride (AuCl) and then to metallic gold.

It is quite well known that a ray of light falling upon a piece of selenium changes its conducting power for electricity. This is not a change of valence but has, it would seem, its bearing upon the problem as a possible change in vibration. The chemical action of light is generally attributed to the vibrations set up among the molecules. Rays having the shortest wave-lengths and the greatest frequency are most active in this respect though all the rays of the visible spectrum have been shown to exert some action. So far as this variation in valence is caused by light then the hypothesis of a change in vibration necessitating a change in equilibrium may well serve as an explanation.

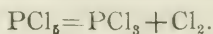
Heat.—Again these variations are often easily brought about by changes of temperature. Thus cupric chloride becomes cuprous chloride.



Mercurous chloride is temporarily changed into mercuric, the mercurous re-forming upon cooling.



Phosphorus pentachloride becomes the trichloride.



Arsenic pentoxide becomes trioxide.



An interesting series of changes are those in the sulphur chlorides. Thus sulphur tetrachloride (SCl_4) becomes sulphur dichlorine (SCl_2), if warmed above -22° , and this becomes sulphur monochloride (S_2Cl_2), if heated above 64° . This last can be boiled without change.

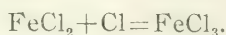
These instances might be multiplied but it is not necessary. The most plausible explanation offered as to the effect of

heat is a change in the velocity of vibration, and it may well serve to explain the variations caused in valence.

Electricity.—Changes of valence due to electricity are probably not unusual but few observations concerning them have been recorded. One of the most noteworthy is the production of carbon monoxide from carbon dioxide by the passage of the electric spark.

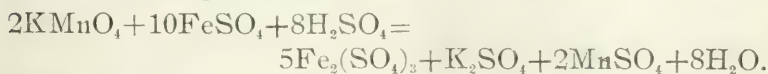


Chemical Action.—The most usual method of bringing about a change of valence is by chemical action. When the change is from a higher proportion of the negative element to a lower it is commonly called *reduction*, and the reverse change is spoken of as *oxidation*. These terms are apparently relics of an older theory, and are confusing, especially to a student beginning the study of chemistry. They should be limited to cases of the actual removal or addition of oxygen. Thus, to speak of the change of ferrous to ferric chloride by the action of chlorine as an oxidation is careless and incorrect.



It is pushing the type theory rather far to speak of the salts of one valence as being derived from the oxide of that valence and yet this is frequently done.

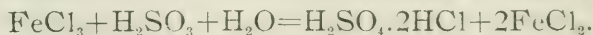
When we take ferric chloride and let sulphurous acid act upon it, it is called a reduction of the ferric chloride to ferrous chloride, although certainly no oxygen is removed from the ferric chloride nor is oxygen added when the ferrous chloride is changed again to ferric chloride by the action of nitric acid, and still this is called an oxidation. The use of terms for these reactions is evidently in need of revision. What shall we call the following reaction, cited by Drechsel as an "oxidizing action?"



Some hydrogen is oxidized with the formation of water but that is not what is meant. The manganese is changed from its highest valency to its lowest and the iron from its low-

est to a higher. The permanganate is of course deoxidized.

It seems that chemical action may induce change when to an existing molecule a third substance is offered capable of combining with one or more of its constituent atoms, thus releasing the former equilibrium. Thus when sulphurous acid takes the oxygen of water setting hydrogen free the hydrogen then takes one of the chlorine atoms held by the iron.



But the presence of all three of these molecules is needed for the reaction to take place. So too, potassium permanganate is stable in the presence of sulphuric acid, unless the ferrous sulphate or some such molecules are present. When molecules of these three substances come together there is immediate rearrangement of molecules with change of equilibrium. Whether we are dealing here with a play of affinity which causes the tumbling down of certain molecules and building up of others, or whether it is a question of vibratory equilibrium between these molecules, cannot yet be told. The only certain thing seems to be that a molecule containing bivalent iron and another containing septivalent manganese cannot exist in the presence of one another but must change, when possible, to trivalent iron and bivalent manganese.

As meagre as our present knowledge is, it does not seem to be a very hopeful task to enter the maze of changes of valence through chemical reactions with a view to clearing up the ideas as to the nature of valence.

Explanations Offered.—Victor Meyer and Riecke have supposed that a solution of the problem could be arrived at best by studying the phenomena of frictional electricity, contact electricity, pyro-electricity, and electrolytic conductivity. Most of those who have suggested hypotheses have based them upon a study of the carbon atom and its compounds and in particular its space relations. I have gathered together such of these hypotheses as have come to my notice.

The first in point of time is the hypothesis of van't Hoff¹.

¹ Ansichten über die organische Chemie I. 3.

His idea is that valence is dependent upon the form of the atom. He says: "The simplest observation teaches that every change from the spherical form must lead to greater changes in the attraction in certain directions, since the atom at these points can, so to say, be more closely approached. Each form of that kind therefore determines a certain number of capacities for attraction or valences."

Ostwald¹ comments upon this hypothesis as follows:

"If we think of valence as a question of a property of the atom, whose action can be modified by the difference in the condition of the atom, especially in its motion, then it is thinkable that although the cause of the valence is unchangeable, the workings of this cause, that is the valence itself seems to differ from case to case.

An hypothesis of this kind has in fact been suggested by van't Hoff. In that he assumed that the chemical attraction between the atoms was a consequence of gravitation, he showed that if an atom possessed a form differing from the spherical the intensity of the attraction on its surface must possess a definite number of Maxima. The Maxima can be of varying value. If the motion of the atom from heat is energetic only the greatest Maxima will be able to hold their atoms and the valence shows itself to be smaller by higher temperatures than by lower which corresponds with observation.

Lossen's² idea as to valence, deduced from the consideration of the theories of van't Hoff and Wislicenus as to the space relations of the atom, seem to be condensed into the simple sentence:

"This conception leads, in my opinion, necessarily to the assumption that the polyvalent atom cannot be regarded as a material point but that rather parts of it are to be distinguished from which the influence goes out to other atoms."

Wislicenus³ expressed his ideas as to valence as follows:

"I consider it not impossible that the carbon atom more or

¹ Lehrbuch der allg. Chemie I ed. I, 830.

² Ber. d. Chem. Ges. 20, 3309.

³ Ber. d. Chem. Ges. 21, 581.

less, perhaps right closely, resembles in its form a regular tetrahedron; and further that the cause of those influences which reveal themselves as units of affinity concentrate themselves in the corners of this tetrahedron herhaps, and from analogous grounds, just as the electric influences would do from an electrically charged metallic tetrahedron. The real carriers of this energy would be the primitive atoms as the chemical energy of a compound radical is undoubtedly the resultant inherent energy of the elementary atoms.

Victor Meyer and Riecke¹ advanced the hypothesis that the atom is surrounded with a spherical shell of ether: the atom is the seat of chemical affinity, the surface of the ether shell that of valence. Each valence is determined by the presence of two oppositely electrified poles which form the ends of a line short in comparison with the thickness of the shell.

The hypothesis of Knorr² may also be given in brief. He assumes in each atom the presence of Valenzkörper which have the power of attracting other Valenzkörper. The quantivalence of any atom is determined by the number of these present.

Flawitzky³ takes as a basis for his hypothesis the suggestion of N. Beketoff that the cause of the chemical interaction of the elements lay in the interference or coincidence of the motions of the atoms. The chief assumption is that the atoms of each element described closed curves which lie in planes, which are parallel to one another and have a constant absolute position in space. The atoms of different elements move in planes which made definite constant angles with one another. According to Flawitzky, thus, "the valences of the elements can be refered to the differences in the angles between the planes of the paths of the different atoms."

It is quite possible that other hypotheses as to valence have been formulated but have escaped my notice. These

¹ Ber. d. Chem. Ges. 21, 951.

² Ann. Chem. (Liegbig) 279, 202.

³ Ztchr. Amorg. Chem. 12, 182.

will suffice to give the more recent trend of thought upon the subject. I may state that none of these were known to me when the first paper was sent on for publication¹ as I had not deemed it necessary to look beyond the usual text-books in examining into the literature upon the subject. This statement is not made for personal reasons as that is a matter of small moment, but that there may attach to my hypothesis whatever of value there is in the independent reaching of a conclusion.

It is not pertinent to this paper to discuss at any length the citations just given. But a few words are needed to bring out certain differences and distinctions. In most of them we have the assumption of some peculiar form of energy—an "Anziehungskraft." Flawitzky alone makes no explicit assumption of the kind. Besides this assumed force, which is the point of contention after all, we have various other assumptions of a remarkable character; *e. g.*, as to the forms of atoms, envelopes, primal atoms, and *Valenzkörper*. Flawitzky's hypothesis is based upon the angles made between the planes in which the atoms move.

Now in the place of all this I wish to substitute that which seems to me to be the simpler hypothesis of vibratory equilibrium. There is only one attractive force to be considered and this is called chemical affinity and causes the union of the atoms, binding them together. These atoms may unite atom with atom, or one atom with two or three or more atoms of the other element or other elements. While we speak of union there is no actual contact to be assumed. The individual atoms have their own motion and at the same time the aggregation of atoms, or molecule, has a motion proper to it. The conditions of equilibrium in such a system determine the number of atoms which can enter it: as one to one, one to two, etc. There is no distinct force of valence determining this. The form of the atoms can scarcely be taken into consideration because the distance between the atoms is too great, compared with the mass of the atom, for the form

¹In the Journal of the American Chemical Society.

to exert much influence, unless it influences the character of the motion. The atomic weight also has little influence in determining the number of atoms needed to satisfy the conditions of equilibrium except that there seems to be a general rule that with increase in the atomic weight in any one group more stable equilibrium is brought about with the smaller number of atoms and in a choice between several the lesser valence is preferred. (Compare nitrogen and bismuth; sulphur and tellurium.)

There would then appear to be seven, possibly eight, different kinds of motion among the atoms. Different velocities of vibration are not meant, but different phases of motion. For instance, all may have elliptical orbits with different focal distances; or circular, with different radii, etc. In any group of elements the motion of the atoms would have one common characteristic but there would be differences in velocity. In the first and seventh group, showing, for the most part, a tendency towards the same equilibrium, or having the same valence, the motion must be closely analogous. So too for the second and sixth groups, the third and fifth. There may then be a necessity for four distinct phases only, unless we suppose a fifth for the eighth group. If the motion of an atom can be changed from one character to another its valence is changed and in such general properties as are dependent upon motion and not upon atomic weight it is equivalent to changing its group. Electricity, light, heat, and chemical action can cause this change of motion. In so far the properties of the element are subject to change and within our control. But the other factor, atomic weight, with the properties of the element determined by it, is not subject to change nor within our control, so far as our knowledge goes.

While it is freely granted that there is so much of the speculative in what has been said as to make us touch the whole subject with extreme caution, and while it is further admitted that it is quite beyond the reach of present experimental research, yet it is believed that the use of the imagination is legitimate and tends toward the advancement of the science

so long as the true value is set upon it and fancy is not allowed to obscure fact nor to be mistaken for it. The hypothesis proposed is simple and if true will be very helpful. It will be a great step forward if it can be shown that the doctrine of valence is a doctrine of vibratory equilibrium.

PRELIMINARY CATALOGUE OF THE BIRDS OF
CHAPEL HILL, N. C., WITH BRIEF NOTES
ON SOME OF THE SPECIES.

T. GILBERT PEARSON.

INTRODUCTION.

In this catalogue are enumerated the species of birds, known to have been observed and positively identified at Chapel Hill. While the list is incomplete, and is presented only as a preliminary catalogue, the author expresses the hope that it may prove of use to those interested in the ornithology of the region, and that it may serve as a basis for more extended observations. In addition to the enumeration of the species, the paper contains some brief notes on the migration and nesting habits of such forms as have come under the writer's observation at Chapel Hill.

The difficulty of preparing a complete catalogue of the birds may be readily understood when we recall the fact that the bird population is constantly changing. The great wave of the autumnal migration carrying large numbers of northern birds past us, at the same time taking many of our summer forms, scarcely subsides, before the swell sets back from the south, sweeping hosts of birds of passage to us on their northern journey. Some migrants found to be numerous during the fall migration may be extremely rare in the spring, and *vice versa*. Birds which normally do not occur in a

region are sometimes taken, having wandered, or having been driven by storms far out of their natural range. In certain species some individuals are always migratory, while others are permanent residents.

Again it is well known that a form which is abundant some years, may be seen but rarely or not at all in after years. The changing area of the food products for birds naturally brings about a change in the area of their habitat. Hence it may easily be seen that continual observation during a number of years is absolutely necessary before anything like a complete list of the *avi-fauna* of a particular region can be hoped for.

Data.—My observations on the bird life of Chapel Hill began in September 1897, and were continued up to the following April; then again from September 1898 until June 1899. With the exception of ten days in the latter part of June 1898, I had no opportunity for studying the region in summer. During the fall migration in 1897, the main part of which extended over the month from September 15 to October 15, a portion of twenty-one days was spent in the field in a special study of the warblers. Sixteen species of warblers were secured during this period.

In gathering material for the catalogue much assistance was rendered by members of my ornithology class at the University of North Carolina, in 1898, and again during the spring of 1899. Of those whose aid has been especially valuable, I would mention Mr. George McNider, Mr. E. H. Hartley and Mr. Ivy Lewis. I am indebted also to Dr. Kemp P. Battle, whose close observations on the birds of the neighborhood, extending over a period of many years, I found very valuable.

In the Journal of the Elisha Mitchell Scientific Society, Part 2 for 1887, Prof. George F. Atkinson published a "Preliminary Catalogue of the Birds of North Carolina," in the preface of which he remarks, "In all, about 120 species have been observed and absolutely identified by myself at Chapel Hill." In his catalogue, however, Professor Atkinson omits

to indicate the species which he had there noted. A clipping from the "Raleigh News and Observer," presumably printed about this time has been kindly loaned me by Mrs. R. W. McRae. The clipping contains a "Preliminary list of birds collected in the vicinity of Chapel Hill," by Professor Atkinson. In this communication are enumerated ninety-two species. Two of the forms there mentioned have not been included in the present list. The first of these, the tame pigeon (*Columbia livia domesticata*), is excluded as not being a native wild bird. The other form, the clay-colored sparrow (*Spizella pallida*), was listed by Professor Atkinson on the strength of a single specimen. This specimen is still preserved in the Biological Laboratory, and is a fair type of the swamp sparrow (*Melospiza georgiana*). In the case of all other birds, included in the News and Observer list, and with which I have not myself met, mention is made of Professor Atkinson as the observer.

My own observation in the field, specimens brought in by others from time to time for identification, and Professor Atkinson's two papers, constitute the data, from which the present list has been compiled. In all one hundred and nineteen species of birds at Chapel Hill have actually come under my notice.

It may be of use to mention here some of the collections of birds now in North Carolina, which are accessible to the public. In the Biological Laboratory at the State University, in Chapel Hill, there is a collection of some 350 skins and mounted specimens. The State Agricultural Museum at Raleigh contains a beautiful collection of several hundred mounted birds. The collection of birds in the Museum of Natural History at Guilford College is numerically nearly as great. All of these collections are constantly growing.

The Field.—The field for the study of bird life about Chapel Hill is in many respects a good one. The woods, open fields, small streams, and underbrush make a varied environment which tends to bring together large numbers of forms. On the other hand the absence, in the immediate

neighborhood, of large streams and ponds, keeps away many varieties of ducks, sandpipers, and birds of similar habits.

Terms used.—The nomenclature adopted by the American Ornithologists' Union is followed, and the vernacular name succeeds the scientific. In some cases well known local names are also added. The terms "common," "rare," "abundant," etc., which are used in speaking of the occurrence of birds, are of course relative and not altogether satisfactory, but they may convey something of the original idea intended.

Family Podicipidae.

1. COLYMBUS HOLBOELLII (Reinh.) Holboell's Grebe. One specimen recorded by Prof. Atkinson, taken at Chapel Hill in 1877. The skin is now preserved in the university collection.

2. PODILYMBUS PODICEPS (Linn.) Pied-billed Grebe; Diederich's Grebe; Water-witch. One was shot near town and brought me on November 3, 1897. Others have been taken but the bird probably occurs only in winter.

Family Urinatoridae.

3. URINATOR IMBER (Gunn.) Loon; Great Northern Diver. Occurs only as a migrant or winter visitor. The two specimens in the university collection bear no date of capture.

Family Anatidae.

4. SIX SPONSA (Linn.) Wood Duck; Summer Ruck. A male in fine plumage was killed in "Strowd's low-grounds" from a small flock by Mr. H. E. Mechling on January 3, 1898. Others have been reported at various times. Possibly breeds.

Family Ardeidae.

5. BOTHAURUS LENTIGINOSUS (Montag.) American Bittern; Thunder Pumper. Recorded by Prof. Atkinson as occurring at Chapel Hill.

6. ARDEA HERODIAS (Linn.) Great Blue Heron; Blue Crane. "These birds used to fly over here years ago but I have not noticed one, I am sure, for the past twenty years." —Dr. Kemp P. Battle.

7. *ARDEA EGRETTEA* (Gmel.) American Egret. A specimen was shot north of the village by the late Mr. Dedrick in 1894. Doubtless a rare summer straggler.

8. *ARDEA VIRESCENS* (Linn.) Green Heron. A common summer resident about the mill-ponds and along the creeks. A nest containing fresh eggs was found near the village by Mr. George McNider during the first week of May 1899.

Family Rallidae.

9. *PORZANA CAROLINA* (Linn.) Sora. One in the university collection was taken in November 1887, at Chapel Hill.

10. *FULICA AMERICANA* (Gmel.) American Coot; Blue Peter. The only record is by Prof. Atkinson. "One walked into Mr. McCauley's store at Chapel Hill on the night of April 8, 1887, at 8 o'clock, and was captured. A heavy wind and storm was prevailing, and had continued all day."

Family Scolopacidae.

11. *PHILOHELA MINOR* (Gmel.) American Woodcock. A rather common resident, but owing to its very retiring habits is not often seen. Noticed one on the University campus November 10, 1898.

12. *GALLINAGO DELICATA* (Ord.) Wilson's Snipe; English Snipe. Not uncommon in winter and during migration.

13. *TOTANUS SOLITARIUS* (Wils.) Solitary Sandpiper. Listed by Prof. Atkinson. This bird probably appears at Chapel Hill only as a migrant or occasional winter visitor.

14. *ACTITIS MACULARIA* (Linn.) Spotted Sandpiper. Catalogued by Prof. Atkinson. Its habits are quite similar to those of the Solitary.

Family Charidriidae.

15. *AEGIALITIS VOCIFERA* (Linn.) Killdeer. The killdeer is commonly met with during the fall and winter months. It is highly probable, however, that it is a regular resident, nesting in favorable localities in the surrounding country.

Family Tetraonidae.

16. *COLINUS VIRGINIANUS* (Linn.) Bob-white; Quail; Partridge. An abundant resident at all times of the year.

Family Phasianidae.

17. *MELEAGRIS GALLOPAVO* (Linn.) Wild Turkey. A resident at Chapel Hill. Have seen seven specimens. Four of these were shot near town, and three I observed alive. In November, 1898, one flew across the campus from the southern side and pitched near the Episcopal church building. They haunt at all seasons the large tract of woodland just south of the University, and quite likely construct their nests in some of the sedge fields near by.

Family Columbæ.

18. *ZENAIDURA MACROURA* (Linn.) Mourning Dove. Of common occurrence at all seasons. Its frail nest containing two pure white eggs may often be found on the boughs of the apple-tree or the horizontal limbs of the pine.

Family Cathartidae.

19. *CATHARTES AURA* (Linn.) Turkey Vulture; Turkey Buzzard. A very common bird at all seasons of the year, rearing its young usually in hollow logs or stumps in the deep woods.

20. *CATHARISTA ATRATA* (Bartr.) Black Vulture: South Carolina Buzzard. Watched a flock of Black Vultures flying northward over the campus November 1, 1897. On November 10 others were seen. During the winter of 1898-'99 these birds again appeared in the neighborhood. It is doubtful if they ever breed in this region.

Family Falconidae.

21. *CIRCUS HUDSONIUS* (Linn.) Marsh Hawk. An adult male was shot one mile east of town and brought to me on April 5, 1899. This is the only record for Chapel Hill.

22. *ACCIPITER VELOX* (Wils.) Sharp-shinned Hawk. A rather rare winter visitor. The mounted specimen in the University collection was shot by Mr. George McNider on January 23, 1898.

23. *ACCIPITER COOPERI* (Bonap.) Cooper's Hawk. A common resident. A nest of fresh eggs was taken by Mr. George

McNider on April 29, 1898. This is the hawk whose inroads on the poultry yard are most destructive.

24. *BUTEO LINEATUS* (Gmel.) Red-shouldered Hawk. While it seems reasonable to think this would be a common bird here only one pair have come to my notice. During the spring of 1898 a pair were often watched as they circled through the air above the grove south of the University campus.

On May 9, 1899, I took from their nest in a pine tree, thirty feet from the ground, a clutch of two handsomely marked eggs. Incubation was well advanced at this date.

25. *BUTEO LATISSIMUS* (Wils.) Broad-winged Hawk. The only one of this species known to have been taken at Chapel Hill is the one brought to me for identification by Mr. George McNider on April 15, 1899, which specimen is still retained in his private collection. It was a female and was shot a few miles south of here. Its stomach contained the remains of a frog and a quantity of bird feathers.

26. *HALIAEETUS LEUCOCEPHALUS* (Linn.) Bald Eagle; American Eagle. On March 27, 1898, I watched an adult bald eagle circling about in the air near the northwestern entrance of Battle's Park. As the bird was not over one hundred yards above the earth at the time, its white head, neck and tail could be easily seen. It must be regarded as a very rare bird in this section.

27. *FALCO SPARVERIUS* (Linn.) American Sparrow Hawk. A moderately common resident hawk. Three fresh eggs were found in a nest located in the cavity of a dead pine tree in May, 1898, by Mr. E. H. Hartley. For the past two years a pair of these birds have spent the winter months on the University campus. Their favorite roost was under the eaves of the New East Building.

Family Beronidae.

28. *SYRNIUM NEBULOSUM* (Forst.) Barred Owl; Hoot Owl. Have frequently heard them calling in Battle's Park, and January 18, 1899, a male, which had been wounded, was brought into the Biological Laboratory.

29. *MAGASCOPS ASIO* (Linn.) Little Screech Owl. The

shivering notes of this little owl may be heard about the groves and campus during all seasons of the year. Especially is this true in the late summer when the young of the year, then about grown, join with their parents in the nightly serenade. Their nests are placed in the hollows of trees.

30. *BULO VIRGINIANUS* (Gmel.) Great Horned Owl. For a large bird the horned owl is a fairly common resident in this region. Its domicile is usually located in the natural cavity of some tree or in an old hawk or crow's nest. The eggs are deposited early in the year. A female shot on January 21, 1899, contained two well developed ovarian eggs.

Family Cuculidae.

31. *COCYZUS AMERICANUS* (Linn.) Yellow-billed Cuckoo; Rain Crow. A well known plaintive cry from orchard and forest is the note of the rain crow in summer. It retires to the south on the approach of autumn.

Family Alcedinidae.

32. *CERYLE ALCYON* (Linn.) Belted Kingfisher. Observed occurring along the creeks in autumn, winter and spring. May possibly breed.

Family Picidae.

33. *DRYOBATES VILLOSUS AUDUBONII* (Var?) Hairy Woodpecker. Two specimens were taken during the winter of 1897-'98. It is probably a rare resident.

34. *DRYOBATES PUBESCENS* (Linn.) Downy Woodpecker. An abundant resident, associating often with the Titmouse and Chickadee. The downy spends the long winter nights in holes which it hollows out of the dead limbs of trees for this purpose.

35. *SPHYRAPICUS VARIUS* (Linn.) Yellow-bellied Sapsucker. A common winter form. It often girdles trees with numerous small holes which it drills for the purpose of drinking the sap. The apple, spruce pine and maple are among the trees which thus suffer.

36. *CEOPHLOEUS PILEATUS* (Linn.) Pileated Woodpecker.

This large handsome woodpecker is not an uncommon bird in Battle's Park and adjoining woods. On November 8, 1897, I watched one for many minutes pecking about on the trees in the college campus. Without doubt the bird breeds in the large timber near by.

37. *MELANERPES ERYTHROCEPHALUS* (Linn.) Red-headed Woodpecker. A resident. Locally and occasionally common.

38. *MELANERPES CAROLINUS* (Linn.) Red-bellied Woodpecker. This large spotted "sapsucker" is a not abundant resident with us at all seasons.

39. *COLAPTES AURATUS* (Linn.) Flicker; Yellow Hammer. An abundant resident. This woodpecker has acquired the habit of procuring its food so largely by digging it out of the earth that it may now be regarded as more of a ground bird than a dweller in trees.

Family Caprimulgidae.

40. *ANTROSTOMUS CAROLINENSIS* (Gmel.) Chuck-will's-widow. On the night of May 20, 1899, I listened to one of these birds calling for over half an hour. It seems to be in the neighborhood of the campus wall near the south-east corner. So far as I am aware this is the only record of its occurrence in Chapel Hill. It may possibly be found to be a rare summer resident in Orange county.

41. *ANTROSTOMUS VOCIFERUS* (Wils.) Whip-poor-will. A common summer visitor, depositing its two marble looking eggs on the ground in the woods, with only a few dead leaves between them and the earth. The first one noted in the spring of 1899 announced its arrival from the south by its loud cry on the night of April 20.

42. *CHORDEILES VIRGINIANUS* (Gmel.) Nighthawk; Bullbat. A common spring and autumn transient. A few may linger through the summer to breed. First one seen in 1899 was in the afternoon of April 27.

Family Micropodidae.

43. *CHAETURA PELAGICA* (Linn.) Chimney Swift; Chimney

Swallow. A common summer resident, arriving from the south early in April. First one noted for 1899 was on April 12. Before the white man came with his chimneys the swift built its nest in hollow trees.

Family Trochilidae.

44. *TROCHILUS COLUBRIS* (Linn.) Ruby-throated Hummingbird. Of the four hundred species of hummingbird known to occur in America, the ruby-throat is the only one found east of the Mississippi. It is a common summer resident at Chapel Hill, arriving during the latter half of April.

Family Tyrannidae.

45. *TYRANNUS TYRANNUS* (Linn.) Kingbird; Bee Martin. This little pugilist, which does not hesitate to attack any intruder which comes near its nest, is a common summer resident about Chapel Hill.

46. *MYIARCHUS CRINITUS* (Linn.) Crested Flycatcher. An abundant summer resident, building its nest in cavities of trees or stumps seldom more than twenty feet from the ground. The bird has the habit of using among its other nesting materials a cast snake skin. First arrival for 1899 noted April 21.

47. *SAYORNIS PHOEBE* (Lath.) Phoebe; Pewee. Summer resident. First noted in 1899 on April 30. Eggs have been taken by Mr. McNider.

48. *CONTOPUS VIRENS* (Linn.) Wood Pewee. Common summer visitor.

49. *EMPIDONAX VERESCENS* (Vieill.) Acadian Flycatcher. Listed for Chapel Hill by Prof. Atkinson. Probably a common summer bird.

Family Aladidae.

50. *OTOCORIS ALPESTRIS* (Linn.) Horned Lark; Shore Lark. Two specimens were brought me on November 23, 1898. They were said to have been shot from a flock of about twenty individuals. This bird can be expected only as an irregular winter visitor.

Family Corvidae.

51. *CYANOCITTA CRISTATA* (Linn.) Blue Jay. An abundant resident, nesting in large numbers in the trees about the campus and village. A set of five eggs taken from a nest on May 11, 1899, were slightly incubated.

52. *CORVUS AMERICANUS* (Aud.) American Crow. Common bird. Breeds in numbers.

53. *DOLICHONYX ORYZIORUS* (Linn.) Bobolink; Reebird; Ricebird. Occurs as a fall and spring migrant, but not a common species at any time. I noticed a flock of six individuals consisting of two males and four females on the campus May 20, 1899.

54. *AGELAIUS PHOENICEUS* (Linn.) Red-winged Blackbird. A resident, but never a very abundant bird. It builds its nest in the bushes and trees along creeks.

55. *STURNELLA MAGNA*. Meadowlark; Old Field Lark. Of common occurrence in autumn and winter. During the winter months of 1898-'99 a flock of about forty individuals remained constantly on the college campus. The birds may possibly breed in limited numbers in this region.

56. *ICTERUS SPURIUS* (Linn.) Orchard Oriole. Not an uncommon spring visitor, and very probably remains through the summer to nest.

57. *SCOLECOPHAGUS CAROLINUS* (Mull.) Rusty Blackbird. Two were shot by Mr. Ivy Lewis on February 3, 1899, from a small flock, which was feeding along the branch in the grove just south of the campus. Later in the month several others were seen.

58. *QUISQULUS QUISQULA* (Linn.) Purple Grackle. Mr. McNider noted a small flock of these on Easter Monday, 1898. On December 28, 1898, I saw one on the college campus. They probably do not spend the summer in Orange county.

Family Fringillidae.

59. *CARPODACTUS PURPUREUS* (Gmel.) Purple Finch. An abundant winter resident. They appear to have a great relish for the buds of the wahoo or winged elm (*Ulmus alatus*) and may often be seen in large numbers feeding on these trees.

60. *PASSER DOMESTICUS* (Linn.) House Sparrow; English Sparrow. An abundant resident. They multiply rapidly, each pair of birds raising several broods in a season.

61. *SPINUS TRISTIS* (Linn.) American Goldfinch; Yellow-bird; Lettuce bird. A familiar bird throughout the year.

62. *POECAETES GRAMINEUS* (Gmel.) Vesper Sparrow; Bay-winged Bunting. Winter visitor, rather rare.

63. *AMMODRAMUS SANDWICHENSIS SAVANNA* (Wils.) Savanna Sparrow. Common winter visitor.

64. *AMMODRAMUS SAVANNARUM PASSERINUS* (Wils.) Grasshopper Sparrow. Seen in winter and spring. A few may breed.

65. *ZONOTRICHIA ALBICOLLIS* (Gmel.) White-throated Sparrow. An abundant winter sojourner, associating in flocks often in company with the snowbird (*Junco*). Earliest arrival noted in 1897 was on October 4.

66. *SPIZELLA MONTICOLA* (Gmel.) Tree Sparrow. Listed by Prof. Atkinson probably as a winter occurrence.

67. *SPIZELLA SOCIALIS* (Wils.) Chipping Sparrow. One of our most abundant summer birds, building its nest in the trees and bushes about the campus. First spring arrival for 1899 was seen on April 11.

68. *SPIZELLA PUSILLA* (Wils.) Field Sparrow. Common summer resident. It nests in low bushes or on the ground.

69. *JUNCO HYEMALIS* (Linn.) Slate-colored Junco; Snowbird. This is one of our best known winter friends, and is met with in numbers from the time of its arrival late in the autumn until the warm April days. It then leaves for its summer home in the north. There is a common saying about the country that this bird in the spring turns to a sparrow, and in the fall of the year again assumes the dark coat and hood of the snowbird. My first record of its arrival in the fall of 1897 is October 30.

70. *PEUCAE AESTIVALIS BACHMANII* (Aud.) Bachman's Sparrow. "One taken from a breeding pair by myself at Chapel Hill. The nest was found by Willie Gullick; eggs 4, size .63x.70, dull whitish; nest a bulky structure on the

ground made of coarse grasses." — *Atkinson's Catalogue*. It is probably a regular summer resident.

71. *MELOSPIZA FASCIATA* (Gmel.) Song Sparrow. A common winter visitor. Its strong clear song is one of the characteristic notes of a winter's evening in the fields about Chapel Hill.

72. *MELOSPIZA GEORGIANA* (Lath.) Swamp Sparrow. A common winter visitor.

73. *PASSERELLA ILIACA* (Merr.) Fox Sparrow. This handsome brown fellow, the largest of all our sparrows, is a common though not an abundant winter bird. It avoids the open fields and may be found along the borders of thickets and in shrubbery. The first one seen by myself in the fall of 1897 was on November 17.

74. *PIPILO ERYTHROPHthalmus* (Linn.) Towhee; Chewink; Swamp Robin. This is a common bird during the migrations, haunting the thickets and the border of wooded streams.

75. *CARDINALIS CARDINALIS* (Linn.) Cardinal; Redbird. These beautiful and interesting birds are constant residents in this region. Their nests, composed mainly of twigs and leaves and lined with rootlets are generally situated in small trees. Three or four is the number of eggs deposited. May is the usual month for breeding.

76. *HABIA LUDOVICIANA* (Linn.) Rose-breasted Grosbeak. A rare spring transient.

77. *GUIRACA CAERULEA* (Linn.) Blue Grosbeak. Recorded by Prof. Atkinson. Found to occur only in the summer.

78. *PASSERINA CYANEA* (Linn.) Indigo Bunting; Indigo-bird. An abundant summer resident, building its nest in small trees and bushes a few feet from the ground,

Family Tanagridae.

79. *PIRANGA ERYTHROMELAS* (Vieill.) Scarlet Tanager. Rather a rare spring transient. Have seen them in April and May.

80. *PIRANGA RUBRA* (Linn.) Summer Tanager; Summer

Red-bird. An abundant and conspicuous denizen of the groves and orchards in summer. It constructs a nest of leaves, small strips of bark, and grass, situated usually on a horizontal limb from ten to twenty feet from the ground.

Family *Hirundinidae*.

81. *PROGNE SUBIS* (Linn.) Purple Martin. Have seen only a few. These came as spring migrants. They would likely spend the summer and breed, if suitable nesting places, such as bird boxes on poles, were furnished them. I know of none that nest here, nearer than eight miles from town. Dr. Kemp P. Battle informs me that forty years ago these birds were common summer residents.

82. *CHELIDON ERYTHROGASTER* (Bodd.) Barn Swallow. Common transient.

83. *TACHYCINETA BICOLOR* (Vieill.) Tree Swallow; White-bellied Swallow. A common spring migrant.

84. *STELGIDOPTERYX SERIKIPENNIS* (Oud.) Rough-winged Swallow. A summer visitor. Eggs secured by Mr. McNider from a hole in a clay bank in June 1899. I believe to be of this species.

Family *Ampelidae*.

85. *AMPELIS CEDRORUM* (Vieill.) Cedar Waxwing; Cedar-bird. The sad lisping notes of the cedar-bird is one of the most common sounds in the winter forest. The birds at this season usually associate in flocks of a few dozen individuals, and are often found clinging to the boughs of cedar trees, the berries of which they are very fond of eating. It probably nests here.

Family *Laniidae*.

86. *LANIUS LUDOVICIANUS* (Linn.) Loggerhead Shrike. Rather a rare winter visitor. I have observed six individuals at Chapel Hill.

Family *Vireonidae*.

87. *VIREO OLIVACEUS* (Linn.) Red-eyed Vireo; "Hanging bird." A common summer form.

88. *VIREO FLAVIFRONS* (Nieill.) Yellow-throated Vireo. One taken by myself May 20, 1899. Will doubtless be found to be of regular summer occurrence.

89. *VIREO SOLITARIUS* (Wils.) Blue-headed Vireo. I secured a specimen on October 8, 1897, and within a week three other birds were seen. It may be looked for with success only during the spring and autumn migrations.

90. *VIREO NOVEBORACENSIS* (Gmel.) White-eyed Vireo. Prof. Atkinson records it as a "rare summer visitor."

Family *Mniotiltidae*.

91. *MNIOTILTA VASIA* (Linn.) Black-and-White Creeping-Warbler. Common summer resident, nesting on the ground in the woods. Have found it more numerous during the fall migration. This attractive little white and black striped acrobat is apparently equally at home while searching for food along the under side of a limb, or clinging head downward on the huge bole of some forest tree.

92. *HELMITHERUS VERMIVORUS* (Gmel.) Worm-eating Warbler. Listed by Prof. Atkinson.

93. *COMPSOTHYLIS AMERICANA* (Linn.) Parula Warbler. An abundant species in the spring and autumn. Is doubtless a summer resident also.

94. *DENDROICA AESTIVA* (Gmel.) Yellow Warbler. Summer resident.

95. *DENDROICA CAERULESCENS* (Gmel.) Black-throated Blue Warbler. Common migrants. I have usually found them haunting thickets bordering woodland streams.

96. *DENDROICA CORONATA* (Linn.) Myrtle Warbler; Yellow-rumped Warbler. Plentiful in fall and spring, some remaining through the winter months.

97. *DENDROICA MACULOSA* (Gmel.) Magnolia Warbler. I have found this a rare bird at Chapel Hill. Have taken only two specimens, one a male on September 24, 1897, the other a female five days later.

98. *DENDROICA PENNSYLVANICA* (Linn.) Chestnut-sided Warbler. Found only in transit. Have seen but one bird, it being a male taken on September 21, 1897.

99. *DENDROICA CASTANEA* (Wils.) Bay-breasted Warbler. On October 2, 1897, about six o'clock in the morning I shot a female *D. castanea* and on October 8, another, a male. They are extremely rare birds, these being not only the first taken at Chapel Hill but are the first recorded in North Carolina. The skins of both specimens are preserved in the university collection.

100. *DENDROICA STRIATA* (Forst.) Black-poll Warbler. Rather rare transient. Took a female on October 9, 1897.

101. *DENDROICA BLACKBURNIAE* (Gmel.) Blackburnian Warbler. Have found this only as a rare bird of of passage. Secured a female on October 16, 1897.

102. *DENDROICA DOMINICA* (Linn.) Yellow-throated Warbler. Spring migrant. Have observed but few.

103. *DENDROICA VIRENS* (Gmel.) Black-throated Green Warbler. I found this not an uncommon fall migrant. Took a female October 2, 1897.

104. *DENDROICA VIGORSII* (Aud.) Pine Warbler. A common resident. Have not found the nest. The bird is said to build on horizontal limbs of pine tree from twenty to sixty feet from the earth.

105. *DENDROICA PALMARUM* (Gmel.) Palm Warbler, (more probably the var. *D. p. hypochrysea*, (Ridgw.)) Listed by Prof. Atkinson.

106. *DENDROICA DISCOLOR* (Vieill.) Prairie Warbler. Summer resident, not uncommon.

107. *SEIURUS AUROCAPILLUS* (Linn.) Oven-bird; Golden-crowned Thrush. A migrant. First one seen in spring of 1899 was on April 14.

108. *SEIURUS NOVEBORACENSIS* (Gmel.) Water-thrush. Not a very common transient. Have only seen a few specimens.

109. *SEIURUS MOTA CELLA* (Vieill.) Louisiana Water-thrush. Common summer resident. Observed as late in the fall of 1897 as September 21. First one seen in 1899 was on April 12.

110. *GEOTHLYPIS TRICHAS* (Linn.) Maryland Yellow-throat. A summer bird doubtless breeding here.

111. *ICTERIA VIRENS* (Linn.) Yellow-breasted Chat. An abundant summer resident. Found usually along the border of woods or haunting the growths of bushes in open fields along streams.

112. HOODED WARBLER, Catalogued by Prof. Atkinson. Is probably a rare summer resident.

113. *SETOPHAGA RUTICULLA* (Linn.) American Redstart. A common migrant and a rather rare sojourner in summer.

Family Motacillidae.

114. *ANTHUS PENNSILVANICUS* (Lath.) American Pipit; Titlark. About nine o'clock on the morning of January 4, 1899 I saw a flock of fully one hundred titlarks in the open piece of ground at the eastern side of the university campus. Have on two other occasions observed flocks of these birds at a distance, but always during the coldest parts of the winter.

Family Troglodytidae.

115. *MIMUS POLYGLOTTOS* (Linn.) Mockingbird. Several pairs of these birds are constant residents at Chapel Hill. There is a great difference in the musical power of different birds of this species. An especially fine singer, has for the past two years or more dwelt among the shade trees of the lawns in the neighborhood of the Episcopal church.

116. *GALEOSCOPTES CAROLINENSIS* (Linn.) Catbird. An abundant species in summer. The first ones arrive from the south near the middle of April.

117. *HARPORHYNCHUS RUFUS* (Linn.) Brown Thrasher; Brown Thrush. These fine songsters come regularly to spend the summer in the thickets and groves about the village. Rarely also they spend the winter here. On January 2, 1899, I observed one on the lawn surrounding the home of Prof. Harrington. It was in company with a number of snowbirds and sparrows, and had apparently taken up its winter abode among them.

118. *THYOTHORUS LUDOVICIANUS* (Lath.) This is one of the few species of birds which sing for us in the winter. It

remains here through the summer, breeding abundantly. The nest is made of a great quantity of dried grass, strings, leaves and other materials, and is placed in a wide variety of positions; such as in old tin cans hung up in trees, in knot holes, or under the eaves of houses, and under brush heaps in the woods. On May 17, 1899, I was shown a nest containing six eggs, which was built in a man's cap hung against the slatted side of an out-house.

119. *TROGLODYTES AEDON* (Vieill.) House Wren. Listed by Prof. Atkinson. Probably a rare transient.

120. *TROGLODYTES HIEMALIS* Vieill.) Winter Wren. Common in winter.

121. *CERTHIA FAMILIARIS AMERICANA* (Bonop.) Brown Creeper. Common in winter, but not abundant.

Family Paridae.

122. *SITTA CAROLINENSIS* (Lath.) White-breasted Nuthatch. Common resident. Nests in holes in tall trees, early in April.

123. *SITTA PUSILLA* (Lath.) Brown-headed Nuthatch. Have frequently found them in the pine groves in April and May.

124. *PARUS BICOLOR* (Linn.) Tufted Titmouse. Common resident. Eggs number from four to six, and are deposited in the cavities of trees.

125. *PARUS CAROLINENSIS* (Aud.) Carolina Chickadee. A common and noisy resident; often associating in small flocks in company with the titmouse. The nest is made in holes in small trees or posts, from five to eight eggs being deposited.

Family Sylviidae.

126. *REGULUS SATRAPA* (Licht.) Golden-crowned Knight A winter resident. It is worth a search in the winter forest to get a glimpse of this most exquisite gem of diminutive bird life, with his olive-green coat and bright orange and yellow crest. His summer home is among the evergreens of the mountains, and of the far north.

127. *REGULUS CALENDULA* (Linn.) Ruby-crowned Knight. Have found it to be a less abundant species than the foregoing. More common during the migration period.

128. *POLIOPTILA CAERULEA* (Linn.) Blue-gray Gnatcatcher. Very abundant summer resident, breeding in April and May. Eggs four to six.

Family Turdidae.

129. *TURDUS MUSTELINUS* (Gmel.) Wood-Thrush; Wood Robin. This is the most abundant and characteristic summer bird of Chapel Hill, building the nest for its four greenish-blue eggs in the shade trees of the lawns and streets. The first arrival noted from the south in the spring of 1899 was one heard singing on April 22.

130. *TURDUS FUSCESCENS* (Steph.) Wilson's Thrush. Noted by Prof. Atkinson. Probably seen in transit.

131. *TURDUS USTULATUS SWANSONII* (Cal.) Olive-backed Thrush. Occurs only as a migrant. One specimen taken September 26, another October 9, 1897.

132. *TURDUS AONALASCHKAЕ PALLASII* (Cab.) Hermit Thrush. The common winter thrush.

133. *MERULA MIGRATORIA* (Linn.) American Robin. A well known resident. Breed, building their nests in shade and orchard trees.

134. *SIALIA SIALIS* (Linn.) Bluebird. Since the severe cold weather early in the year 1893, which proved so destructive to bird life in the Eastern States, the bluebird has been scarce. Of late, however, the species is beginning to assume more nearly its former numbers.

Oct. 1, 1899.

Guilford College, N. C.

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JOURNAL
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SIXTEENTH YEAR———PART SECOND

1899

ON THE UNIVERSAL DISTRIBUTION OF TITANIUM.¹

BY CHARLES BASKERVILLE.

The universal distribution of titanium in the mineral and plant world is practically acknowledged. V. Roussel² found it in basalt; Aleksiejew³ in certain clays. Holland⁴ found it in certain igneous rocks. Dunnington⁵ observed its occurrence in the soil of Albemarle County, Va.; later the same writer with McCaleb⁶ found it in sixteen specimens of soil collected from different sections of the United States. Subsequently after having examined a large number of samples of soil collected from all parts of the globe Professor Dunnington⁷ asserted its universal occurrence in the soils of the world.

W. A. Noyes⁸ found it in a number of Arkansas minerals. Hillebrand has shown its presence in a large number of rocks and minerals collected by the United States Geological Survey. Wait⁹ found it in the ashes of several plants and different

¹ *J. Am. Chem. Soc.*, XXI, 1099.

² *Ber. d. chem. Ges.*, 6, 1417, b.

³ *Chem. Ztschr.*, Rep. 1896, 261.

⁴ *Chem. News*, 59, 27.

⁵ *Proc. A. A. A. S.*, 34, 132.

⁶ *Am. Chem. J.*, 10, 36.

⁷ *Am. J. Sci.*, Dec., 1891; *Chem. News*, 65, 65.

⁸ *J. Anal. Appl. Chem.*, 5, 39.

⁹ *J. Am. Chem. Soc.*, 18, 402.

kinds of wood, also in coals, bituminous and anthracite. Haywood¹ found traces in domestic strawberries and 0.1088 per cent. in the ash of wild strawberry (*Fragaria Virginiana*). Langenbeck speaks frequently of its occurrence in clays. It has been found by the writer rather widely distributed in the clays of this state.² While Roscoe and Schorlemmer state that "It does not appear to form a part of the animal and vegetable kingdom," Wait³ assumes that it is assimilated by plants. The writer⁴ shows its presence in peat. As the clay substance therein is comparatively small its presence can scarcely be attributed to that. F. Garrigon found traces in mineral waters.

No statement in the literature has been found of its presence being noted in the ashes obtained from the animal kingdom. The ash from incinerated fresh beef, beef bone, human flesh, and bone free from dirt, have been examined in this laboratory with the following results: Beef bone 0.0195 per cent.; beef flesh 0.013 per cent.; human bone⁵ a trace; human flesh⁶ 0.0325 per cent. titanic oxide.

A private communication from Dr. J. L. Howe concerning the work of some of his students states that "Toole found titanium in abundance in dead bones, but only traces in fresh bone and muscular tissue, though traces were undoubtedly there." Dr. C. E. Wait in a letter of recent date writes: "Since my note on titanium was published a year or so ago, I have made an examination of a large number of bodies and I believe that the element was found in nearly all of them. I have made a large number of estimations of titanium in vegetable bodies, and later took up the examination of animal

¹ This laboratory. Work unpublished.

² See "Clay Deposits and Clay Industry in N. C." Bulletin 13, N. C. Geological Survey, by Dr. H. Ries.

³ *Vide supra*.

⁴ *J. Am. Chem. Soc.*, 21, 706.

⁵ A true rib and clavicle.

⁶ Pectoral muscles, *latissimus dorsi* and *gluteus maximus*. I am indebted to Dr. C. S. Mangum, of this University, for kindly dissecting out these samples.

flesh and bone, and the last piece of work along that line was the examination of human excretory products."

The universal distribution of titanium in all forms of living and dead matter may now be regarded as settled. While no opinion is hazarded by the writer upon the role played by titanium in animal and vegetable growth, it is hoped that Dr. Wait's work will throw some light upon the subject. Doubtless had we as delicate and convenient tests for the other less common elements we should find their occurrence as widespread. Thus the asseverated belief of Hillebrand in the universal occurrence of the elements in the earth's crust is extended.

Titanium was determined by Weller's well-known method as modified by W. A. Noyes, Dunnington, and Hillebrand.¹

THE OCCURENCE OF VANADIUM, CHROMIUM, AND TITANIUM IN PEATS.²

BY CHARLES BASKERVILLE.

Attention has been called by Dr. W. F. Hillebrand³ to the comparatively wide-spread occurrence of vanadium in a large number of minerals and rocks. He states that "Hayes in 1875 reported its occurrence in a great variety of rocks and ores. Quoting from Thorpe's 'Dictionary of Chemistry,' it is said to be diffused with titanium through all primitive granite

¹ Method ascribed to Noyes was previously published by F. W. Clark in *Silliman's Journal*, 1868. (Letter to writer.)

² Read before the North Carolina Section of the American Chemical Society at the midwinter meeting. *Publ. J. Am. Chem. Soc.* 441, 706.

³ *Am. J. Sci.*, 6, 209 (1898).

rocks (Dieulafait) and has been found by Deville in bauxite, rutile, and many other minerals, and by Bechi and others in the ashes of plants and in argillaceous limestones, schists, and sands.....' It is further reported to comprise as V_2O_5 0.02–0.07 per cent. of many French clays, 0.02–0.03 per cent. of some basalts, 0.24 per cent. of a coal of unknown origin, and 0.45 per cent. of one from Peru, amounting to 38.5 per cent. and 38.0 per cent. of the ash, and noted respectively by Murlot and Torrico y Meca.”

Roussel¹ states that a basalt with a content of 0.707–2.378 per cent. of titanium contained 0.006–0.023 per cent. of vanadium. Gladstone,² however, states that it does not occur in the volcanic dust of Vesuvius. Terreil³ found it in iron ores. Stolba⁴ also mentions its occurrence.

From the above the presence of vanadium could with reason be suspected in peat. In the hands of the writer were samples of peats from Hyde Swamps, one mile south of Pungo Lake near the Northern Junction of Beaufort and Hyde Counties, N. C. The approximate analysis of these peats gave :

| Sample. | Water. | Volatile matter. | Fixed carbon. | Ash. |
|---------------|--------|------------------|---------------|------|
| Peat I..... | 73.67 | 16.16 | 9.72 | 0.45 |
| Peat II..... | 71.58 | 17.42 | 10.31 | 0.69 |
| Peat III..... | 76.01 | 14.19 | 9.32 | 0.48 |

The water was determined by taking a cube measuring about eight cm. each way (from 700 to 800 grams) and bringing to a constant weight by heating for a number of hours not higher than 105 C. An analysis, approximate, of this dried peat gave the following results:

| Sample. | Volatile matter. | Fixed carbon. | Ash. |
|---------------|------------------|---------------|------|
| Peat I..... | 61.38 | 36.90 | 1.72 |
| Peat II..... | 61.35 | 36.20 | 2.45 |
| Peat III..... | 59.13 | 38.85 | 2.02 |

It was convenient to examine the ash of a large number of

¹ *Ber. d. chem. Ges.*, 6, 1417 b.

² *Ibid.*, 5, 815 b.

³ *Ibid.*, 10, 731 a.

⁴ *Chem. Centrbl.* (1897), 121.

peats from this and other localities to ascertain the presence of titanium. We have found no statements regarding the presence of this element in these ashes, although such a surmise was logical. Neither does chemical literature, as far as we have been able to examine, give any mention of the occurrence of chromium in peats. Appended are the results of seeking for these elements in the samples mentioned above.

| Sample. | Titanic oxide. | Chromium sesquioxide. | Vanadium pentoxide. Percentages in ash. |
|---------------|----------------|-----------------------|---|
| Peat I..... | 0.490 | 0.0283 | 0.00107 |
| Peat II..... | 0.340 | 0.0343 | 0.0026 |
| Peat III..... | 0.491 | 0.0355 | 0.0031. |

In determining titanium the ash was decomposed according to the method of W. A. Noyes,¹ namely, by fusion with sodium fluoride and potassium pyrosulphate. The melt was brought into solution with Dunnington's² necessary precaution in mind: *viz.*, having from five to ten per cent. of sulphuric acid present. Hydrogen dioxide was added according to Weller's³ well-known method and the titanium determined colorimetrically. All hydrofluoric acid was driven off in the fusion and the hydrogen dioxide was free from that acid as well. Hillebrand⁴ has shown the necessity for this.

Chromium⁵ and vanadium⁶ were estimated according to the latest method of Hillebrand.

A STUDY OF CERTAIN DOUBLE CHROMATES.

BY W. G. HAYWOOD.

Zehenter has stated (*Monatshefte f. chemie* 18, 48 55 Cen-

¹ *J. Anal. Appl. Chem.*, 5, 39.

² *J. Am. Chem. Soc.*, 13, 210.

³ *Ber. d. chem. Ges.*, 15, 2592.

⁴ *J. Am. Chem. Soc.*, 17, 718; *Chem. News*, 72, 158.

⁵ *J. Am. Chem. Soc.*, 20, 454.

⁶ *Ibid.*, 20, 461; *Am. J. Sci.*, 6, 209.

tral Blatt, 97.I.857, that when a boiling solution of potassium bichromate is neutralized with sodium carbonate according to this equation,



then concentrated over the direct flame and over sulphuric acid, first the double salt $3\text{K}_2\text{CrO}_4 \cdot \text{Na}_2\text{CrO}_4$ will crystallize out in the form of flat or column-shaped crystals, then a salt of the same composition with one half molecule of water and finally yellow crystals of the salt $\text{Na}_2\text{CrO}_4 \cdot 4\text{H}_2\text{O}$. The sodium chromate prepared by Johnson which crystallized with ten volumes of water was not obtained. Zehenter also prepared the salts $3\text{K}_2\text{CrO}_4 \cdot 2(\text{NH}_4)_2\text{CrO}_4$ and $\text{NaNH}_4\text{CrO}_4 \cdot 2\text{H}_2\text{O}$ by precipitation with alcohol from the appropriate solutions.

For my experiments the following solutions were prepared:

1. 100 grams of potassium bichromate were dissolved in water and neutralized with sodium carbonate.
2. 100 grams of sodium bichromate were dissolved in water and neutralized with potassium carbonate.
3. 100 grams of ammonium bichromate were dissolved in water and neutralized with sodium carbonate.
4. 100 grams of sodium bichromate were dissolved in water and neutralized with ammonium carbonate.
5. 200 grams of potassium bichromate were dissolved and neutralized with sodium carbonate (repeating No. 1).
6. 110 grams of potassium bichromate and 98 grams of sodium bichromate were dissolved in hot water and evaporated.
7. 67 grams of potassium chromate and 60 grams of potassium carbonate were dissolved and evaporated.
8. 100 grams of potassium bicarbonate were dissolved and neutralized with magnesium carbonate.
9. 100 grams of potassium chromate and 55 grams of sodium carbonate were dissolved in hot water.

All of these solutions were concentrated and then placed over sulphuric acid for crystallization. The crops of crystals were carefully separated, washed, dried between filter paper and analyzed.

In the case of this solution (1) the crystals which first formed were found to contain a good deal of carbon dioxide. It was evident that the solution had not been exactly neutralized by the sodium carbonate but that an excess had been used. With successive crops the amount of carbon dioxide decreased and of chromium increased. Although the analysis of the third and fourth crops approached nearly to that of the double chromate reported by Zehenter, traces of carbon dioxide were found throughout, and so another solution was prepared and more carefully neutralized. But the evident crystallizing together of the chromate and carbonate raised the question as to the possible formation of a body of exact composition containing these two. In the case of solution (1) the first crop of crystals was practically all chromate and the seventh and later crops again strongly carbonate. In solution (7) when potassium chromate and potassium carbonate were mixed several crops of crystals were gotten, the first being almost pure chromate and the latter carbonate, the two showing little tendency to crystallize together.

In solution (2) the 3rd crop of crystals gave 27.45 percent. Cr.; 4th crop, 28.10; 5th crop, 27.15; 6th crop, 28.03. There was a failure in this case also to prepare crystals of definite composition.

From solution (3) three crops of very deliquescent brown crystals were gotten which corresponded in composition to the formulas $2\text{Na}_2\text{CrO}_4 \cdot (\text{NH}_4)_2\text{CrO}_4 \cdot 4\text{H}_2\text{O}$.

From solution (4) crop (a) seemed to be a mixture, yielding nothing definite; crop (b) consisted of crystals of $\text{NaNH}_4\text{CrO}_4 \cdot 2\text{H}_2\text{O}$; crops (c) and (d) gave sodium chromate, $\text{Na}_2\text{CrO}_4 \cdot 4\text{H}_2\text{O}$, differing from the ordinary chromate with ten molecules of water.

Solution (5) yielded first potassium bichromate and then a large number of crops of large flat hexagonal crystals which had the composition $3\text{K}_2\text{CrO}_4 \cdot \text{Na}_2\text{CrO}_4$.

Solution (6) yielded no new compound, the two bichromates crystallizing out separately.

Solution (8) yielded a large number of crops of the double chromate of potassium and magnesium $\text{K}_2\text{CrO}_4 \cdot \text{MgCrO}_4 \cdot 2\text{H}_2\text{O}$.

Solution (9) gave crystals of carbonate containing no chromium and also crystals of the salt $3K_2CrO_4 \cdot Na_2CrO_4$.

This work in the main confirms that of Zehenter though it introduces some new modes of formation of the double salts. It gave rise to some interesting questions though the time was too brief to answer them.

ORIGIN OF PALEOTROCHIS.¹

BY J. S. DILLER.

Prof. Ebenezer Emmons,² while State Geologist of North Carolina, discovered among the so-called Taconic rocks of Montgomery County, in that State, a number of more or less regularly striated bi-conical forms to which he gave the names *Paleotrochis* major and minor, and regarded them as siliceous corals as well as the oldest representatives of animal life upon the globe. According to Emmons, *Paleotrochis* varies in size up to two inches in diameter, and occurs with many almond shaped concretions, often within concretions, in a series of beds over 1,000 feet in thickness interstratified with beds of granular quartz, conglomerate and quartzite.

¹ This paper is reprinted here from the *American Journal of Science* (May, 1899, page 337) as a substitute for an article which the present writer had intended publishing, setting forth the same general data and conclusions. Mr. Diller's work has removed all doubt as to the mineral origin of *Paleotrochis*; and the republication of his paper in the *Mitchell Journal* is considered advisable owing to the intimate association of the *Paleotrochis* with local North Carolina geology, and the previous publication in this journal of Mr. White's paper (see note below) which argued in favor of the organic origin of this interesting form.

² Geological Report of the Midland Counties of North Carolina, 1856, page 62; also *Am. Jour. Sci.*, II, vol. xxii, page 390, and vol. xxiv, page 151.

Both species of *Paleotrochis* have the form of "a flattish double cone applied base to base" with the surfaces grooved somewhat irregularly from near the apex to the basal edge. The smaller form, *P. minor*, has the "apex of the inferior side excavated or provided with a small roundish cavity" and the other apex "supplied with a small rounded knob, from the base of which the radiated grooves begin." The larger form, *P. major*, "differs from the foregoing (*P. minor*) in the absence of the roundish apical depression of the lower side and the knob of the opposite side."

Prof. Emmons regarded *Paleotrochis* not only as originally siliceous but also gemmiferous, thus accounting for knobs as well as irregular adhering groups, and it is important to note that he reports "these fossils also occur in a variety of quartz or quartzite which I have described as a buhrstone, and which is often porphyryzed."

Prof. James Hall,¹ after an examination of many specimens, regarded the *Paleotrochis* of Emmons as nothing but concretions in quartz rock. Prof. O. C. Marsh² examined the forms microscopically and found them composed of fine-grained quartz, but no trace of organic structure could be detected. While maintaining its inorganic nature he regarded it as difficult to explain, and considered it as having some analogy with cone-in-cone, which he thinks is probably due to the action of pressure on concretionary structure when forming.

The most extensive paper on this perplexing form is that of Mr. C. H. White,³ who strongly advocates the organic nature of *Paleotrochis*. The specimens he examined were those obtained by Prof. Emmons, as well as a number collected by Prof. J. A. Holmes, the present State Geologist of North Carolina. Mr. White describes in detail not only the peculiarities of the weathered surface of the rock but also the features exhibited upon a fresh fracture, and called attention

¹ Am. Jour. Sci., II, vol. xxiii, page 278.

² Am. Jour. Sci., II, vol. xlv, page 218.

³ This Journal 1894. Pt. 2, 50-66.

for the first time to the radial fibrous mineral which he regarded as impure chalcedony. According to Mr. White, the fossil forms are enveloped in chalcedony and the small concretions are made of the same material.

In 1887, Prof. J. A. Holmes¹ visited the Sam Christian Gold Mine of Montgomery County, N. C., and studied the Paleotrochis-bearing rock in the field. Although he had not then seen any of the acid volcanic rocks from New England, described by Dr. M. E. Wadsworth, or from the South Mountain region of Maryland and Pennsylvania, subsequently described by Dr. G. H. Williams and Miss Florence Bascom, he was of the opinion that the rocks in the neighborhood of the Sam Christian Gold Mine were of eruptive origin. Later observations have convinced him of the correctness of this view. The same opinion is entertained by Messrs. H. B. C. Nitze and George B. Hanna,² who consider the Paleotrochis-bearing rocks at the Sam Christian and Moratock Mines as ancient acid volcanics, and state that "it appears highly probable that at least some of these siliceous pebbly concretions are spherulites." Unfortunately in the preparation of their report time did not permit the authors to study thin sections.

The specimens which, at the request of Mr. C. D. Walcott, the Director of the U. S. Geological Survey, the present writer has had an opportunity to study, consist of a small collection³ from Mexico sent by Prof. H. S. Williams, besides three fragments about nine inches in diameter sent by Prof. J. A. Holmes, who collected them in 1887 at the Sam Christian Gold Mine, North Carolina, and from the same place several dozen of the original specimens of Paleotrochis major and minor collected by Prof. Emmons. Specimens of the rock and isolated fossils, excepting those from Mexico, have been cut and polished and thin sections prepared for microscopical study.

The rock from North Carolina which contains Paleotrochis

¹ Letter to the author Feb. 6, 1899.

² North Carolina Geological Survey, Bul. No. 3, pages 37 and 39.

³ See Prof. Williams' article, *Am. J. Sci.*, 335, 1899.

is full of nodules of various shapes and sizes, ranging from that of a pin's head to nearly two inches in diameter. These are the supposed concretions and fossils. Upon a fresh fracture the rock appears to be composed chiefly of quartz, but when weathered most of the nodules become white as if kaolinized, while the other nodules and the matrix remain quartzose in appearance. The nodules form at least two-thirds of the mass of the rock and are arranged with their longer diameters parallel, rendering the rock rather easily split in one direction.

With a lens, it may be seen that the small kaolinized nodules exposed in section upon the surface of a hand specimen have a radial fibrous structure. The same structure may be seen in some of the larger ones, and in addition to this feature some of the nodules possess a more or less distinct concentric shell-like structure. These structures are usually best displayed upon or close to a weathered surface. Portions of the nodules or spaces between them are in a few cases cellular, and the walls of the openings are rarely lined with minute crystals. The supposed fossil forms usually appear conical or discoidal upon a weathered surface. They often show a small cup in the apex and are surrounded by a narrow depression from which the radial fibrous envelope, pointed out by Mr. White, has been removed by weathering.

A careful comparative study of the nodules in the hand specimens tends to convince one that however different in form and size the supposed fossils and concretions may appear, all belong to one series and have essentially the same origin.

A microscopical study of thin sections of the rock reveals the fact that the nodules are spherulites, a common feature of acid igneous rocks. They are composed in most cases chiefly of fibrous feldspar with quartz or tridymite. As seen in the thin section of the Palcotrochis-bearing rock, the fibres are grouped radially with more or less irregularity in tufts, sheaves, sectors, hemispheres or spheres. When they form a complete sphere, which is rarely the case, they are most

coarsely fibrous or granophytic at the center and usually show between cross nicols an indefinite black cross. Occasionally also the concentric structure is well marked. The rays are too minute to permit of an accurate determination of their mineral composition by optical methods, but microchemical tests with hydrofluosilicic acid yield the small cubic crystals, characteristic of potassium fluosilicate as well as the hexagonal prisms of sodium fluosilicate. Judging from the greater abundance of prisms than cubes the fibrous feldspar is richer in sodium than potassium. That feldspar, instead of chalcedony, is the most prominent constituent of the spherulites, is fully borne out also by its kaolinizing under the influence of the weather.

The spherulites are embedded in a matrix composed chiefly of granular quartz. The grains are occasionally so large that the uniaxial positive character can be readily determined. Untwinned feldspar in small grains may be present in considerable amount but yet be easily overlooked. The quartzose character of the weathered matrix, however, shows that at least where most coarsely granular there cannot be much if any feldspar present in it. In places the matrix contains numerous minute parallel scales of what appears to be sericite. Associated with the most coarsely crystalline areas are a few scales of brown biotite and occasionally considerable green biotite, which in places is so abundant as to make quite prominent dark green spots. Both matrix and spherulites are traversed in a few cases by small veins of granular quartz, showing that there is a considerable amount of secondary quartz present. Both spherulites and matrix are rendered slightly microporphyritic by containing occasional crystals of plagioclase feldspar and quartz. The plagioclase, which, on account of its small angle of symmetric extinction, must be an acid one, in some cases forms the center from which the spherulitic fibres radiate.

An isolated specimen of *Paleotrochis* was cut through the apices and found to be composed of granular quartz. The quartz was fine-grained upon the outside where the grains

were set with their longest axes perpendicular to the adjoining surface. The middle portion contained an irregular iron-stained cavity possibly due to the disappearance of some iron-bearing mineral. Several of the half embedded forms of *Paleotrochis* were cut in a hand specimen to discover its relations to the enclosing rock, and in each case it formed the interior portion of a spherulite. Most of them contained a dark green patch. The exposed conical surface of one was well striated and there was an irregular depression in the apex. The form was composed chiefly of granular quartz with a yellowish brown to dark green, strongly pleochroic, biotite. Near the center is a small spherulite which is not only bordered by finer-grained quartz but is cut by a small vein of it, showing that the deposition of the quartz is subsequent to the development of the spherulite. The embedded portion of *Paleotrochis* is bordered by spherulitic fibres which run approximately parallel to the slope of the conical surface, and it is evident that the casts of these fibers produce the irregular striæ or grooves upon the surface of the supposed fossil. The embedded portion terminated with an irregularly-pointed apex below. The whole form is fine-grained near the border and sends small veins into the adjoining spherulitic shell. These veins are so small as not to be visible upon a polished surface of a hand specimen even with the aid of a pocket lens, but come out distinctly in the thin section. The spherulitic shell by which *Paleotrochis* is enveloped is composed of fibers belonging to a number of centers or lines and yet combined they appear to form one nodule. The biconical form of *Paleotrochis* suggests that it originated as two spherulite sectors of which the apices were the centers from which the fibres radiated. This would seem to be the simplest way to account for the most regular as well as many of the irregular forms, but of the specimens examined I have not been able to find one that certainly originated in that way.

A number of the fossil forms with a well-marked cup in the exposed apex turned out to be flat hemispherical or thin lenticular in section, and are composed wholly of spherulitic fibers.

Although admitting much irregularity, especially on account of the supposed gemmiferous character of Paleotrochis, the ones which have been considered the most characteristic of the fossil are the distinctly biconical forms. These, so far as seen, are chiefly granular quartz with more or less green biotite.

It is important to note also that the dark groups of green biotite occur in the interior of very irregular nodules which have no suggestion in them of Paleotrochis. Irregular flattened lenticular masses of granular quartz with green biotite occur within the spherulites as well as about them. The green mica is found only in the most coarsely granular groups of quartz.

The following chemical analysis, made by W. F. Hillebrand, shows that the rock has the composition of a rhyolite and accords closely with the results of the microscopical study.

Analysis of the Paleotrochis-bearing rock of Sam Christian Mine.¹

| | | |
|--------------------------------------|---------------|--|
| SiO ₂ | 79.57 | |
| TiO ₂ | .11 | |
| Al ₂ O ₃ | 11.41 | with a very little P ₂ O ₅ |
| Fe ₂ O ₃ | .20 | |
| FeO | .70 | |
| MnO | none | |
| CaO } | .21 | |
| SrO } | | |
| BaO | .50 | |
| MgO | a very little | |
| K ₂ O | 3.52 | |
| Na ₂ O | 3.46 | |
| H ₂ O below 105° .. | .18 | |
| “ above “ .. | .61 | (ignition) |

100.02

Recognizing the Paleotrochis rock as an acid volcanic, full of spherulites, it is easy to understand the great variation in

¹ No other constituents looked for.

the form of the nodules. Such rocks are in many places distinctly banded and were long considered siliceous sediments, but by the investigations of Wadsworth, Williams, Bascom and others it has been definitely settled that they are all acid volcanics. These rocks in North Carolina are regarded by Mr. Holmes as pre-Cambrian and since their eruption may have undergone great changes like those of the South Mountain described by Miss Bascom. Some of the supposed fossils are certainly spherulites, and all of them may have been originally. Some broken forms show motion in the mass after the spherulites were developed. That *Paleotrochis*, where most perfectly developed and composed of granular quartz, is the result of deposition, after the spherulitic growths about it and within it had developed, there can be no question, but whether this deposition followed soon after that of the spherulites in the course of solidification or took place in hollow spherulites (*lithophysæ*), or resulted perhaps long subsequently at the time of rock alterations, is not so clear. All this and much more will doubtless be cleared up by the members of the Geological Survey of North Carolina, who were the first to correctly identify the rock and the character of the supposed fossil.

None of the Mexican specimens received from Prof. Williams were cut for microscopical examination. Some of them were clearly of igneous origin, and contained amygdulæ. The *Paleotrochis*-like forms with radial markings appeared to be composed of secondary quartz and probably originated as those of North Carolina.

About a year ago bi-conical forms like *Paleotrochis* were presented by Mr. Kochibi, Director of the of the Geological Survey of Japan to the U. S. Geological Survey. These specimens are now in the National Museum, and are much more regular in form, size, and general appearance than the *Paleotrochis* of North Carolina. They are of a pale pink color with regular bi-conical, striated forms, and in some cases have shallow pits of the apices. They are known in Japan as "*Sorobanishi*" or abacus stones. One of these specimens con-

tains a small fragment of the rock from which these curious specimens were obtained, and it appears to be spherulitic. According to Mr. Willis, who obtained the information directly from Mr. Kochibi, "these stones are found only in rhyolitic tufts. They not infrequently occur much larger than these specimens, possibly up to two inches in diameter or more, and are more frequently associated in groups of two or three overlapping or coalescing. They are generally white, the rosy tint of these specimens being a rare characteristic." A thin section of one of these "abacus-stones" shows it to be an agate of which the outer layers are pink and the inner white. There can be no doubt in this case that the form resulted from the filling of the cavity long after the solidification of the igneous material.

THE DEEP WELL AT WILMINGTON, N. C.¹

BY J. A. HOLMES.

The deep well which is now being bored at Wilmington, N. C., is of especial interest to geologists: (1) That in reaching granite, as it does at about 1109 feet, it shows the absence at this point of the formation between the upper Cretaceous and the old crystalline floor underlying the coastal plain deposits; (2) it shows the existence there of an unfortunately and unusually thick series of salt-water-bearing strata, from 350 to 1100 feet below the surface; (3) it may throw some light on the relations between the deposits of the sand hill regions (generally classed as Potomac) and the upper Cretaceous beds penetrated by this well.

The well is located on the bank of the northeast Cape Fear

¹ *Science*, N. S. XI., 265, Jan. 26, 1900, p. 128.

River, at Hilton Park, one mile north of Wilmington. The river border at this point exhibits two terraces; one only a few feet above tide water, extending back a distance of 30 or more feet from the river; and the other rising 30 to 40 feet higher, extending back for a considerable distance, and indeed representing the general surface of the region. The difference in elevation between these two terraces represents the thickness of the remnants of the Tertiary fossiliferous clays and limestone and the overlying recent sands. The lower terrace represents the upper surface of the Cretaceous; so that the well starts in the Cretaceous clays and sands, and continues in them to a depth of some 1100 feet. In these sands and clays there are occasional beds of shell-rock and calcareous sandstone, varying in thickness from a few inches to 30 feet, and occasional thin beds of clay containing small nodules or concretions. The sands are mostly micaceous and are usually quite fine grained, with a prevailing gray color. From about 700 to 800 feet, their color is decidedly greenish. Below 950 feet these sands become coarser and are interbedded with occasional gravel deposits, but they continue fossiliferous to near the surface of the granite.

Waterbearing sands and gravels were penetrated at a number of points, notably at 380, 496, 520 and 574 feet; and at 1011 the largest flow, of nearly 400 gallons per minute, was encountered, with pressure estimated as sufficient to raise the column of water 80 feet above the surface. Unfortunately the water from each of these levels was highly brackish, and hence unfit for domestic use.

The fossil forms secured at different depths have been identified by Dr. T. W. Stanton, of the United States Geological Survey. The method used in sinking the well is the ordinary drill and sand pump; and, as might be expected, in some cases only fragments of shells were secured; but as the hole was of large diameter (12 inches near the surface, then 10 inches, and lower still, 8 inches) and the larger part of the matrix material quite soft, a minimum amount of drilling was needed; and many large fragments and many perfect forms were obtained.

Among the fossils secured from the upper 700 feet, classed as Ripley cretaceous, the following may be mentioned:

Cardium enfaulense Gabb, was found at 40 feet and 538-558 feet, and fragments of this or another *Cardium* were found also at 50, 485-490, 520-540 and 556-575 feet below the surface.

Anomia argentaria Morton, was also common, having been obtained at frequent intervals from 40 to 600 feet; and fragments of an *anomia*, too small for specific classification, were also found 800 to 900 feet below the surface.

Exogyra costata Say, was abundant throughout the upper half of the section; and below 500 feet a varietal form of this species, approaching *Exogyra ponderosa* Roemer, in surface feature, was found almost to the granite.

Ostrea tecticosta Gabb, was common from 230 to 650 feet; and *O. larva* Lamarck, from 250 to 330 feet; and fragments secured at 518 feet probably belonged to one of these species. *O. subspatulata* Lyell & Forbes, was found only between 332 and 380 feet. Throughout the entire section, however, were found numerous fragments of *Ostrea* too imperfect to serve for specific determinations. *Veleda lutea* Conrad, and *Aphrodina lippana* Conrad (?) were found only at 340 to 500 feet. *Baroda Carolinensis* Conrad, and *Cyprimeria depressa* Conrad, were found only between 332 and 380 feet; and fragments of *Pecten* were found at 40 to 50 feet.

Gryphaea vesicularis Lamarck, was found at 250 to 265, and 720 to 735 feet (?); and *Inoceramus cripsii* Mantell, at 575 to 585 feet and probably also at 500 to 518 feet. Unrecognized species of *Avicula* or *Gervillia* were obtained at 390 to 400 feet; *Corbula* at 492; *Pectunculus* 520 to 540 feet, and *Lunatia* 520 to 590 feet; *Lithophagus* 540 to 560 feet.

Cassidulus subquadratus Conrad, was observed at 518 to 538 feet, and echinoid spines and fragments of the same or allied species were also found at 100 to 170 feet. Sharks' teeth, fish vertebrae, fragments of turtle shell, lignite and pyrite were found at intervals in the section.

Below 720 feet, and down to the granite (1109) *Ostrea cre-*

tacea Morton, which in the Chattahoochee river section is confined to the Eutaw beds, is here quite common; and is accompanied at intervals by *Anomia Exogyra*, *Cardium* and *Serpula*, the specimens collected being in each case too fragmental to permit of specific determination. This lower 400 feet of the Wilmington section has been classed by Stanton as *Eutaw*; and it is possibly the seaward representative of the Potomac arkose sands and clays of the sand-hill region northwest of Fayetteville, should these sands and clays prove to represent the latest Potomac. It is more likely, however, either that the Potomac deposits were removed from this region prior to the Eutaw deposition, or else that the surface of these old crystalline rocks was above water level during Potomac time, and hence not covered with deposits.

Underground temperatures were not taken at intervals at different depths while the work was in progress, owing to the lack of suitable thermometers; but there are now three wells only three or four feet apart, one 1100, one 500 and one 100 feet deep. The temperatures at the bottom of each of these, as determined by the use of a Darton deep well thermometer, were found to be 79°, 72.50°, and 68.50°F. respectively, giving a descending increase in temperature of about 1°F. for each 100 feet, between 100 and 500 below the surface; and 1°F. for each 98 feet, between 500 feet and 1100 feet below the surface.

CHAPEL HILL, N. C.

NEW EAST AMERICAN SPECIES OF CRATAEGUS.

¹CONTRIBUTIONS FROM MY HERBARIUM. NO. VI.

BY W. W. ASHE.

Crataegus pertomentosa n. sp. A small tree, 4-9 meters in height, with horizontal branches forming a round or flattened crown, trunk covered with gray bark broken into oblong

¹Received Feb. 10, 1900.

scales, and often armed with long, gray or dark purple thorns: branches gray, armed with numerous 6-9 cm. long, dark red-brown purplish or nearly black, straight or slightly curved thorns: twig of the season glabrous brownish-red or brown: buds globular, red-brown, glabrous. Leaves broadly ovate or nearly orbicular, obtusely pointed at the apex, broadly cuneate, rounded or even subcordate at base, the blades 4-6 cm. long, 3-5 cm. wide with 5-7 pairs of prominent veins, acutely glandular serrate, doubly serrate or with 3-5 pairs of shallow lobes above, entire at the base, thick, subcoriaceous, dark green, glabrous and lucid above, paler and soft or roughish pubescent beneath: petiole 5-10 mm. long, margined above. The flowers are borne in 4-10-flowered compound tomentose corymbs, the lower branches from the upper leaves: fruiting pedicels strict, 2-4 cm. long, pubescent: styles 3-4: stamens 10-15: calyx pubescent, its acute divisions entire or glandular laciniate. Fruit glabrous 8-13 mm. in diameter, red or yellowish: flesh thick: nutlets 3-4 with shallow furrows on the back.

This tree is related to *Crataegus tomentosa* L. from which it is separated by having smaller, broader and more pubescent leaves, fewer stamens and fewer-flowered corymbs. Type locality: Johnson county, Kansas, where I collected it last year. The type material is preserved in my herbarium.

Crataegus neo-fluvialis n. sp. A small tree 3-5 meters in height with long horizontal branches forming a flattened crown: branches gray, nearly straight or flexuous, armed with numerous slender, red-brown purplish or grayish, straight or slightly curved, 4-7 cm. long thorns: twig of the season red-brown, glabrous, marked with few pale ovate lenticels: winter-buds prominent, subglobose, red-brown, glabrous. Leaves lucid, dark green and nearly glabrous above, scarcely paler and pubescent to glabrate beneath, the pubescence soft and abundant on unfolding, becoming scanty and roughish with age, the blades elliptic or rhombic ovate in outline, 5-10 cm. long including the petiole, acute and entire towards the base which gradually narrows into the mar-

gined petiole, acute at the apex, finely and sharply glandular serrate, above the middle doubly serrate or with 2-3 pairs of shallow lateral lobes, 3-7 pairs of prominent straight parallel deeply impressed veins: petiole short, margined, glandless, 5-15 mm. long. The flowers are in large, 8-15-flowered, nearly glabrous, compound corymbs, the lower branches from the axils of the upper leaves: pedicels strict, 5-20 mm. long: stamens 10-15, longer than the 3-5 styles: divisions of the calyx lanceolate, 5 mm. long, sharply glandular serrate or entire. Fruit 6-9 mm. in diameter, nearly round, greenish, orange or rosy-cheeked, flesh thin and firm: seed 3-5, smooth or slightly ridged on the back, 4-5 mm. long, 3-4 mm. thick dorso-ventrally, the lateral faces concave.

Crataegus neo-fluvialis is related to *Crataegus macracantha* Lodd., from which it is separated by having narrower acute pubescent leaves, and somewhat smaller fruit which lacks the bright red so characteristic of *Crataegus macracantha* Lodd. It is frequent along the North Fork of the New River in Ashe county, North Carolina, and the adjacent part of Virginia. The type material is preserved in my herbarium.

Crataegus Margaretta n. sp. A small tree 4-5 meters in height with rather short horizontal or ascending branches forming an open oval crown, or sometimes a large shrub: branches gray, flexuous or geniculate, unarmed thornless or sparingly beset with short, 2-3 cm. long, slender red-brown thorns, twig of the season geniculate, red-brown, glabrous, marked with numerous, very small gray lenticels: winter-buds subglobose, rather large, the few glabrous scales red-brown. Leaves glandless, glabrous, or at first with a few short hairs on the upper surface, membranaceous, or at length firmer, bright green on both sides, the blades broadly rhombic to nearly orbicular, or even broader than long, 3-5 cm. long, 2.5-6 cm. wide, with 3-6, generally 5 pairs of prominent straight veins, obtusely serrate and with 3-5 pairs of generally shallow lobes above the middle, or deeply lobed on vigorous shoots, obtusely or acutely pointed at the apex, entire or distantly serrate towards the obtuse or broadly wedge-

shaped base: petiole slender, 15-25 mm. long, narrowly winged above. The flowers which appear when the leaves are almost full grown in 7-12 flowered nearly simple corymbs, the lower branches from the axils of upper leaves, are white, 12-15 mm. wide and borne on strict glabrous pedicels 10-22 mm. long: petals orbicular, with a short claw, calyx glabrous, its divisions entire or sparingly serrate: styles 2-3 in number, 5 mm. long overtopping the 15-20 glabrous stamens: bractlets of corymbs and stipules of unfolding twig early deciduous, greenish, not conspicuously colored, spatulate, pectinately glandular. Fruit quite 1 cm. in diameter, nearly round, glabrous, fleshy, reddish or orange, persistent until late in the winter, on strict, slender pedicels: nutlets usually three, about 5 mm. long, the broad convex back deeply grooved and ridged. In eastern Missouri the flowers appear about the middle of May.

Crataegus Margaretta is found from eastern Iowa and southern Illinois to eastern Missouri, generally occurring along small streams. It is apparently related to *Crataegus punctata* Jacq., from which it is distinguished by having fewer-flowered leafy corymbs, smaller fruit, and much broader leaves, which are pointed and have fewer pairs of prominent veins. The type material is preserved in my herbarium. The type locality St. Louis county, Mo.

Crataegus macrosperma n. sp. A small tree 5-7 meters in height, with wide-spreading branches, forming an oval or round crown, the trunk covered with gray-brown bark broken into small oblong scales: branches gray, armed with numerous short, very stout, 1-3 cm. long, dark red-brown or purplish to nearly black thorns: twig of the season rather thick, dark red-brown to purplish, sparingly glaucous glabrous, marked with a few small grayish lenticels: winter-buds rather large, oval or globular, dark red-brown, the obtuse or rounded scales glabrous. Leaves membranaceous but firm, dark green above, paler and sparingly glaucous or whitish beneath, the blades deltoid or broadly oval, obtuse at the apex, rounded, subcordate or on vigorous shoots cordate with a narrow sinus

at the base, varying greatly in size even on the same twig, 3-6 cm. long, 2-5 cm. wide, finely but sharply serrate to the base, doubly serrate or with 3-5 pairs of shallow lobes above, the serratures acutely gland-tipped, 4-6 pairs of prominent veins: petiole 1-2 cm. long, generally short and less than one-third the length of the blade, channeled, narrowly margined, at least above, and with a few glands near the base of the leaf. The flowers, which appear when the leaves are nearly grown in few 4-9 flowered nearly simple corymbs, are white 14-17 mm. wide and borne on slender pedicels: calyx glabrous, its divisions lanceolate, short, 3-5 mm. long, persistent and coloring with the fruit: styles 3-4: stamens 5-10, generally 5, the base of the very stout filaments persistent and coloring with the fruit. The fruit 13-18 mm. in diameter, borne in small clusters, is somewhat longer than thick, a uniform dark but bright red when ripe, glabrous and sometimes sparingly glaucous, flesh thick and mealy, pedicels strict and very slender generally falling with the fruit, which falls from the tree during the latter half of September: nutlets 3-5, deeply grooved and ridged on the back, 5-7 mm. long, 5 mm. thick dorso-ventrally, the lateral faces plane.

Crataegus macrosperma is found in northern Alabama and northwestern Georgia and the adjacent portions of Tennessee, growing frequently along rocky, especially cherty ridges in open woods, or often on exposed and thin-soiled almost untimbered rocks. It is frequent on Lookout Mountain, Tenn., which is the type locality, and where it was first collected by me in 1897, and on the surrounding mountains. This species is related to *Crataegus coccinea* L., or more closely to *C. silvicola* Bead., from which it is separated by having shorter stouter spines, smaller leaves, and much larger fruit. The type material is preserved in my herbarium.

Crataegus coccinioides n. sp. A small tree 4-6 meters in height with numerous spreading or ascending branches forming a round or oval crown: the gray bark of the trunk broken into small scales, often armed with long simple or compound

thorns: branches flexuous, dark gray, armed with numerous dark red or nearly black thorns, 2.5-5 cm. long: twig of the season glabrous, dark purple-brown, marked with a few pale, nearly orbicular lenticels: winter-buds small nearly globular, dark red, glabrous. Leaves glabrous, membranaceous, rather lax bright green above, scarcely paler beneath, the blades ovate, broadly oval or even isodimetric, 4.5-7 cm. long, 4-6.5 cm. wide, acute or obtuse at the apex, truncate, subcordate or on vigorous shoots cordate at the base with a broad open sinus, sharply and irregularly glandular serrate, above doubly serrate or with 3-4 pairs of shallow lateral lobes, entire towards the base, 4-6 pairs of prominent veins: petiole slender, terete, 2-6 cm. long, generally two-thirds the length of the blades, sometimes slightly margined and with a few glands near the base of the leaf. The flowers which expand when the leaves are scarcely half grown in small 5-8-flowered corymbs, are white, 18-20 mm. wide, and on slender 2-3-bracted pedicels: petals obovate 8-10 mm. long: styles 3-4, hairy at the base, shorter than the 20 stamens: calyx glabrous or minutely pubescent, its short divisions glandular serrate or laciniate. The fruit is 8-11 mm. thick, somewhat longer, bright red when mature and persistent until late in winter: nutlets 3-4, 5-6 mm. long, about 4 mm. thick dorso-ventrally, deeply sulcate and ridged on the back. Bracts and stipules lanceolate (lunate on vigorous shoots) glandular, bright colored, persistent until the flowers expand.

Crataegus coccinioides occurs along streams and in moist upland woods from southern Illinois to eastern Missouri. It is separated from the scarlet thorn by having larger leaves on longer petioles and larger fewer flowers. The type material is preserved in my herbarium.

Crataegus collicola n. sp. A small tree 5-8 meters in height with numerous wide-spreading or horizontal branches forming an oval or flattened crown, the gray bark of the trunk broken into flat, oblong scales and occasionally armed with long simple, gray thorns: the nearly straight gray branches armed with numerous, slender, gray or purple-brown, 4-8 cm. long

thorns : twig of the season glabrous, slender, dark brown-purple or gray, marked with few small pale indistinct lenticels : buds small, subglobular, brownish red. Leaves glabrous, at least when mature, firm, the larger ones becoming subcoriaceous, dark green above, somewhat paler beneath, the blades 4-6 cm. long, 2-4 cm. wide, oval and acute at the apex, or obovate and even spatulate and obtuse or rounded at the apex, tapering at the base into a short 5-15 mm. long, glandular margined petiole, or the larger leaves on vigorous shoots nearly orbicular, and abruptly contracted at the base, sharply and irregularly serrate to near the base or the larger leaves doubly serrate, or with 2-3 pairs of shallow lobes, 4-6 pairs of prominent veins : petiole broadly margined, at least above, 5-15 mm. long. The white flowers are borne in numerous, 6-14-flowered, compound, glabrous corymbs : divisions of the calyx lanceolate, acute, entire : styles 4-5. The abundant orange-red or dull red fruit is depressed globose, 8-11 mm. thick, about 8 mm. high : fruiting pedicels strict, 1-2 cm. long : nutlets 4-5, 5-6 mm. long, 3-4 mm. thick dorso-ventrally, slightly grooved on the back, the lateral faces nearly plane.

Crataegus collicola is related to the cockspur thorn from which, and all varieties of it, it is at once separated by having much broader often pointed and lobed leaves and much longer petioles. I collected this tree in the mountains of North Carolina in September, 1897 in Henderson county and near Asheville where it is found in fields and pastures on dry hillsides. The type material is preserved in my herbarium.

Crataegus Illinoensis n. sp. A small tree with an oblong or irregular crown, or a tall shrub with virgate branches. Branches grayish-red or brownish, armed with 3-5 cm. long red-brown thorns. Twigs glabrous bright red-brown, as are the spherical buds. Leaf-blades 5-8 cm. long 4-8 cm. wide, nearly orbicular or slightly obovate and broadly wedge-shaped at the base, obtuse or rounded at the apex, very sharply and glandular doubly serrate, or somewhat 3-7-lobed above, 4-6 pairs of prominent veins, minutely appressed pubescent above, pubescent beneath with rather harsh, short spreadin

hairs: petioles .5-1.5 cm. long, margined above, deeply channeled. The inflorescence is in loose, 7-18-flowered, compound corymbs, the branches 1-3-flowered, the lower from the axils of the upper leaves. The flowers, appearing the latter part of May when the leaves are nearly full grown, are white, 1.5-1.7 cm. wide: petals nearly orbicular, abruptly contracted into a short claw: stamens 7-10, the glabrous filaments 7-8 mm. long, enlarged at the base, one third longer than the 3 stout glabrous styles: calyx tube obconic, 4-6 mm. long, pubescent with spreading hairs, the lanceolate divisions deeply lacinate, appressed pubescent, the serratures gland-tipped: pedicels pubescent, stout, .3-2 cm. long: bracts linear, small, inconspicuous, early deciduous. The fruit, persisting until late in winter, is 8-11 mm. thick, bright red, nearly glabrous, the flesh rather thin and firm: seed 2-4, about 4 mm. long, somewhat grooved and ridged on the back, the lateral faces plane.

This species is related to *C. Biltmoreana* Bead. from which it is separated by having much rounder leaves, larger compound corymbs, and bright red glabrous fruit. Open woods, central Illinois. I refer here to material collected at Wady Petra, Ill., by V. H. Chase, and distributed as *C. macracantha*.

Crataegus pulcherrima n. sp. A small tree 3-4 meters in height. Twigs very slender, 2-3 mm. thick, red-purple, glabrous. Leaf blades 2-4.5 cm. long, oval to nearly orbicular in outline, 3-7-notched above, glandular-denticulate or distantly serrate, obtuse or acute at the entire base, membranaceous, bright green and glabrous on both sides, with 4-6 pairs of prominent veins: petiole .5-2 cm. long, very slender, winged above, roughed with 1-2 pairs of sessile glands. Flowers white, in glabrous, few-flowered, nearly simple corymbs: pedicels .7-1.5 cm. long, glabrous, strict: stamens 10, styles 4-5, calyx divisions, acute, entire, deciduous. Fruit glabrous, yellowish or reddish, 5-7 mm. thick, 6-8 mm. long: seed 4-5, 3-4 mm. long, smooth on the back and the lateral faces plane.

A very distinct species. Southwestern Georgia, and northwestern Florida. Here I refer Nos. 2568 and 2377 G. V. Nash, 1895.

Crataegus Holmesiana n. sp. A small tree 3--5 metres in height, with a rounded or flattened crown and long horizontal or spreading branches armed with numerous 3--4 cm. long straight or slightly curved thorns; or generally a large shrub. Leaves ovate, the blades 4--9 cm. long, 3--6 cm. wide, obtuse or acute at the apex, acute, obtuse or somewhat rounded at the base, coarsely and acuminate serrate all around, the teeth gland-tipped with 5--9 pairs of shallow lobes or doubly serrate, 5--7 pairs of prominent veins, glabrous on both sides or when young sparingly pubescent beneath; petioles terete, slender, 1.5--3 cm. long, generally purplish, and with a few stalked glands on it near the base of the leaf. Flowers in glabrous, nearly simple few-flowered corymbs, white, 1.5--1.7 cm. wide: petals nearly orbicular contracted at base into a short claw: calyx glabrous, the divisions glabrous, nearly entire; bracts and bractlets few, linear, glandular, not conspicuous. Fruit 8--11 mm. thick, red, glabrous, falling early, 3--5 seeded.

This species in its habit resembles *C. mollis*. It is separated from the nearly related species of the *coccinea* group by having much larger leaves with very acute serratures. Central New York.

Crataegus atrorubens n. sp. A small tree or shrub. Branches gray: twigs bright red-brown, rather slender, marked with few pale lenticels: thorns few. Leaves oval, broadly ovate, or even obovate, the blades 3--7 cm. long, 2--5 cm. wide, obtusely and rather coarsely serrate, sometimes with 3--5, shallow lobes towards the obtuse apex, or merely doubly serrate, 4--6 pairs of prominent veins, entire at the rounded or subcordate base, dark green above, slightly paler beneath, membranaceous, when young sprinkled with short appressed hairs on the upper surface, especially on the veins, and pubescent beneath in the axils of the veins, at length glabrate: petioles 1.5--3 cm. long, very slender, finely pubescent, especially on the grooved upper surface. Inflorescence a 6--14-flowered:

loose compound corymb, the glabrous branches generally 3-flowered: pedicels finely pubescent, bearing 1-2 filiform glandless bractlets, the bracts of the branches very few, inconspicuous, spatulate, entire, or minutely glandular denticulate: flowers white 1.5 cm. wide: petals orbicular: calyx soft pubescent, the acute divisions entire: stamens 20, scarcely longer than the 4-5 styles. Fruit globular, 9-11 mm. thick, dark red, glabrous.

Distinguished from *C. coccinea* by having more entire leaves, and being pubescent. St. Louis County, Missouri.

Crataegus polybracteata n. sp. A shrub or small flat-topped tree with spreading branches. Twigs glabrous, armed with stout curved purple-black thorns. Leaves ovate or elliptic, the blades 3-6 cm. long, 2-4 cm. wide, glandular serrate, with 3-7 shallow lobes, or doubly serrate, acute at the apex, acute or obtuse at the entire base, glabrous on both sides: petiole slender, 1-2 cm. long, narrowly margined above. Inflorescence a 4-10-flowered nearly simple corymb, the branches and stout 1-2 cm. long pedicels glandular dotted, and pubescent with rough spreading hairs: branches and pedicels with linear, spatulate, or deeply 3 parted, .5-2 cm. long bracts, which are rough hairy, pectinately glandular, and persist until after the petals fall. Flowers white, 2-2.5 cm. wide: stamens about 15: styles 3-4: calyx pubescent with a few short, spreading hairs: the divisions 4-6 long, pubescent, glandular serrate. The dull red glabrous fruit is 8-11 mm, in diameter and is borne on strict pedicels.

This species is related to *C. rotundifolia* from which it is separated by having smaller more simple corymbs, larger flowers with hairy pedicels, and large persistent glandular bractlets. Ohio to New York. The type is preserved in my herbarium.

NOTE ON A QUALITATIVE TEST FOR TIN.¹

BY CHARLES BASKERVILLE.

Scarcely any instructor in Qualitative Analysis has failed to have difficulty in having his students make a satisfactory separation of arsenic, antimony and tin. Either of the ordinary methods of separation of the arsenic, namely, solution of arsenic sulphide in ammonium carbonate or the solution of the mixed sulphides of tin and antimony in hot concentrated hydrochloric acid, answer very well for the arsenic. The presence of antimony in the hydrochloric acid solution is easily proven by its precipitation upon platinum in the presence of metallic zinc, subsequent solution in dilute nitric or tartaric acid, and so on. The difficulty is in proving the presence of tin. Unless most of the acid has been driven off and the solution well diluted the tin fails to be precipitated on the zinc. We have usually tested the solution directly with mercuric chloride and hydrogen sulphide for tin. These tests are not always satisfactory, more or less doubt existing in the student's mind, especially if all the antimony has not been removed.

Longstaff (*Chem. News*, 80, 282) suggests reversing the test given by Fresenius (*Qual. Anal.*, 8th Edit., p. 217, trans. by Johnson) for molybdic acid. Stannous chloride produces a blue coloration with molybdic acid. He uses ammonium molybdate.

We carry out the test as follows: filter from the diluted liquid any remaining particles of zinc and add a pinch of powdered molybdic acid. A deep blue color shows the presence of tin. We have proved the presence of one part in five thousand with the very roughest conditions under which a most careless student may work. Longstaff states that with every precaution for exclusion of air it is delicate for one part in a million. The color disappears in the presence of concentrated hydrochloric acid.

The presence of arsenic, antimony and zinc compounds has

¹ Read at the Midwinter Meeting of the North Carolina Section of the American Chemical Society February 24th, 1900.

no effect on the molybdic acid. Care should be taken, however, that no small particles of zinc pass into the liquid after filtering, for the nascent hydrogen generated gives the same color reaction.

February 1900.

UNIVERSITY OF NORTH CAROLINA.

NOTE ON A CASE OF SPONTANEOUS COMBUSTION.¹

BY CHARES BASKERVILLE.

In August 1898 a fire occurred in some of the dyed warp of one of the largest cotton mills in this State. Samples of all materials used in the dyeing and sizing of the yarn were sent the writer by the proprietors of the mill with instructions to seek the cause of the fire in detail. Fortunately, as later learned, the fire was discovered in time and extinguished, avoiding very serious consequences. Such a fire was unusual with these mill owners, the first, in fact, in the history of the mill in question, and its recurrence might prove disastrous. It was necessary to learn if some irregularity in the practice or material used could have been the cause or whether it resulted from the action of chemicals surreptitiously placed upon the yarn by some ill intentioned operative.

Their customary procedure was to dye eight warps at a time (1040 lbs.) in a dye bath of two hundred and fifty gallons of water into which have been placed for each one hundred pounds of yarn eight ounces naphthazarin L. W., five pounds sal soda, one half pound Marseilles soap and six pounds salt. The bath was gradually increased to three hundred gallons and then run off. The warps were then washed with three hundred gallons of water at 180° F. and sized.

¹ Read before Midwinter Meeting of North Carolina Section of the American Chemical Society, 1899.

For sizing each one hundred pounds of yarn nine pounds of starch and three pounds of tallow were used. The warps were run off the dyeing cylinders into sacks quite hot and stored away. At the time mentioned these warps were stored away at four o'clock in the afternoon. The fire was discovered at one the next morning.

Enquiry elicited these facts; first fire; all materials had been on hand some time; same dye had been used for long time; no recent new purchase of dye; *the mill shut down for repairs immediately after the dyeing and before the sizing of the warps which caught fire.*

Careful microscopic examination of the yarn showed only such changes in the fibre as resulted from the mechanical strain to which it had been subjected in the spinning and an even distribution of the dye. No spotted effect was observed such as would occur if chemicals in careless or ignorant hands had been placed upon the yarn intentionally or by accident.

The dye used is commercially called "naphthazarin L. W." By analysis and investigation of the patent literature it was found to be a mixture of equi-molecular parts of tetrazo-diphenyl, sodium salt of amido-naphthol disulphonic acid and dihydroxynaphthalene precipitated by and incorporating more or less sodium chloride. The tetrazo bodies under certain conditions, namely, acid, liberate oxides of nitrogen which may oxidize such substances as cotton. No acid was used according to the dyeing formula.

Fires have frequently resulted from the oxidation of fats, as when old greasy rags are packed away in a warm place for a long while. According to the ordinary method of dyeing as practiced in this mill the rapidity of the work does not give time necessary for oxidation which produces heat. In this case two weeks intervened and the tallow used in finishing either being on hand and exposed more or less to the atmosphere during a warm season permitting the oxidation to begin became rancid, or it was purchased rancid. The oxidation of the fatty constituents of tallow once begun con-

tinues with greater rapidity the better the conditions, namely heat, which conditions prevailed in this case.

The tallow used melted at 42° C. Normal tallow melts at from 43° to 46° C. The amount of lard present was therefore comparatively small. The tallow was rancid, reacting acid with litmus paper.

A chemical examination of the burnt portion showed the presence of nitric acid. This would have resulted from the decomposition of the dye which contains much nitrogen. Nitric acid was also detected in other portions of the material *not* charred, showing that the dye had been decomposed partially by the rancid fat, but not to such an extent as where the burning occurred.

The dyeing was done in an alkaline bath (soda) to prevent this decomposition. The excess of this alkali is washed out and then the warp is sized. Rancid fat is acid and the acidity is increased by further oxidation of the fat, especially at the temperature named. This acid is liable to decompose the dye containing azo radicals liberating the oxides of nitrogen, which tend to increase the oxidation. Experimental proof of this was obtained. The warps being confined instead of cooling nurse the heat until the temperature rises to the charring point of cotton. These conditions being allowed to continue fire would result, as happened in this instance.

As stated above, while it is possible that gaseous compounds capable of burning cotton could come from the dye, it is probably not the case here. Certainly there is no danger if the tallow is fresh. The fire therefore may be attributed to the spontaneous combustion produced by the continued oxidation of rancid tallow. The fact that it was rancid was evidence that the oxidation had begun. Tallow that is only slightly rancid may be used with comparative safety when the process is rapidly carried out. The only absolutely safe plan however is to use fresh tallow. The rancidity of tallow shows itself by acid reaction to litmus paper.

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SOME DICHOTOMOUS SPECIES OF PANICUM.

¹CONTRIBUTIONS FROM MY HERBARIUM. NO. VII.

W. W. ASHE.

PANICUM ALBEMARLENSE n. sp. A densely tufted perennial, dark green or purplish in color, 2-3 dm. high. Culms erect, strict, slender, villous with spreading or ascending 3-4 mm. long white hairs, leafy to near the top, barbed at the nodes: internodes much longer than the leaves and sheaths. Stem-leaves 3-5, firm, erect, 2-5 cm. long, 3-4 mm. wide, the longest near the middle of the stem, very gradually tapering to the apex from near the rounded base, pubescent above with long spreading white hairs, especially towards the base, mixed with shorter ones, pubescent beneath with short ascending hairs, the margins very rough and ciliate at the base with a few long hairs: ligule of a few 2 mm. long hairs; basal leaves 1-2 cm. long, 4-7 mm. wide, glabrate, at least when old. Primary panicle 2-4 cm. long, 1.5-3 cm. wide, the numerous branches ascending, on a short peduncle, 1-4 cm. long, or barely exserted: spikelets broadly obovate, 1.5 mm. long, 1.2 mm. wide, first scale acute, one-third the length of the strongly 7-9-nerved second and third scales, which are pubescent with spreading hairs.

PANICUM ALBEMARLENSE is very common in well drained open woods in Beaufort and Hyde counties, N. C., where the type material was collected by me May 26, 1899, near Scranton. It has the same habit and is closely related in character to *P. meridionale* Ashe, from which separated by being larger, having shorter pubescence, and larger spikelets.

I find that there has been previous use of a very similar name or of the same name which I have applied to the three following species of *Panicum*,² so I propose the following changes in their names:

PANICUM SHALLOTTE n. nom. *P. glabrissimum* Ashe, not *P. glaberrimum* Steud.

¹Received Feb. 19, 1900.²Jour. Elisha Mitch. Sci. Soc. 15, part 1, 1898.

PANICUM YADKINENSE n. nom. *P. maculatum* Ashe, not *P. maculatum* Aubl.

PANICUM BOGUEANUM n. nom. *P. annulum* Ashe, not *P. annulatum* A. Rich.

PANICUM AUSTRO-MONTANUM n. sp. A tufted perennial 1.5-2.5 dm. high. Culms very slender, erect, glabrous. Leaves of stem 2-4, spreading, .5-1.5 cm. long, 3-4 mm. wide, broadly lanceolate, narrowed or rounded at the base, light green, thin and soft; basal leaves numerous, somewhat longer than those of the stem; ligule a ring of hairs about 2 mm. long; sheaths very short, one-fourth to one-half the length of the internodes, generally about the length of the leaves, at least the lower pubescent, especially at the throat, with soft spreading hairs 2 mm. long, nodes barbed with soft spreading hairs. Panicle short-peduncled, 1-2 cm. long, and somewhat narrower, the branches spreading; spikelets broadly obovate, .7 mm. long, first scale one-third the length of the faintly 5-nerved glabrous second and third.

This species is related to *P. Cuthbertii* Ashe, from which separated by having pubescent sheaths and broader spikelets; and to *P. curtifolium* Nash, from which it is separated by having much shorter leaves and smaller spikelets. Along mountain streams of northern Alabama and the adjacent parts of Tennessee. Type material is preserved in my herbarium.

PANICUM CURTIVAGINUM n. sp. A tufted perennial. Culms glabrous, very slender, erect, 4-6 dm. high. Stem leaves 4-6, narrowly lanceolate, 4-8 cm. long, 3-5 mm. wide, the upper reduced in size, soft and thin, bright green, glabrous, except for a few 3-4 mm. long cilia at the base of the lower ones, faintly nerved, narrowed to the base, long taper-pointed, spreading or ascending; basal leaves somewhat longer and wider; internoded much longer than the leaves and sheaths, leaves longer than the sheaths; sheaths glabrous; ligule pubescent with white hairs about 1 mm. long. Panicle long-exserted, 3-6 cm. long, 2-3 cm. wide, the numerous branches ascending; spikelets broadly elliptic, quite 1.5 mm.

long, 1 mm. wide, abruptly acute, first scale 1-nerved, glabrous, one-fourth to one-third the length of the strongly 5-7-nerved thin glabrous second and third.

Collected at Petit Bois Island, Mississippi, May 8, 1898, by S. M. Tracy.

PANICUM WILMINGTONENSE n. sp. Perennial growing in small tufts. Culms very slender, erect, 3-4 dm. high, geniculate, pubescent, at least below, with short ascending hairs or above glabrate, at first simple, at length much branched: sheaths close-fitting, pubescent with short ascending hairs, one-half the length of the internodes or less: ligule a row of short white hairs about 1 mm. long. Stem leaves 3-4, shorter than the internodes, 3-6 cm. long, 3-5 mm. wide, broadest near the base, very long taper-pointed, slightly rounded at the base, glabrate or pubescent beneath with short ascending hairs or with a few long hairs on the margin near the base, thick and firm, the margins rough, white and thickened, upper leaves reduced in size: basal leaves equaling the lower stem leaves. Panicle ovate, 3-4 cm. wide, 5-7 cm. long, branches few, at least the lower ascending: spikelets broadly obovate, quite 2 mm. long, nearly glabrous, the 1-nerved first scale, about one-third the length of the glabrate 7-nerved second and third.

Panicum Wilmingtonense is closely related to *P. Atlanticum* but has smaller more acute spikelets, a more slender culm, scantier pubescence and smaller leaves. The type material collected in May, 1899 on the sand hills near Wilmington, N. C., is preserved in my herbarium.

PANICUM SUBVILLOSUM n. sp. A densely tufted perennial, 1.5-3 dm. high. Culms very slender, glabrous above, below pubescent with ascending hairs. Stem leaves 3-5, erect or ascending, lanceolate or narrower, 3-4 cm. long, 3-5 mm. wide, long taper-pointed, rounded at the base, nearly glabrous beneath, above pubescent with long white ascending hairs, margins rough, ciliate, at least near the base with long white hairs, upper stem leaves and basal leaves reduced in size: ligule pubescent with white hairs 2 mm. long: sheaths

pubescent with spreading hairs, much shorter than the internodes. Panicle on a long peduncle, 6-12 cm. long, broadly oval, 2-3 cm. long, 1.5-2.5 cm. wide, branches glabrous, spreading: spikelets broadly obovate, 1.5 mm. long glabrous, the obtuse first scale one third the length of the firm 7-nerved second and third.

Collected by the writer at Carlton, Minnesota, in August, in the simple state. Type material preserved in my herbarium.

Panicum parvipaniculatum n. sp. A densely tufted perennial, perfectly glabrous except the ligule. Culms 2-3.5 dm. high, erect, at length sparingly fasciculately branched and more or less reclining. Stem leaves 3-5, distant, spreading or the upper erect, very much shorter than the sheaths, one-fifth to one-third the length of the internodes, 1-2 cm. long, 2-3 mm. wide, lanceolate, the upper reduced in size, soft, but rough on the upper surface: ligule densely pubescent with hairs about 2 mm. long: basal leaves numerous, tufted, remaining green until after flowering, 2-4 cm. long, 4-5 mm. wide. Panicle exserted on a peduncle 3-5 cm. long, small, broadly ovate, 2-3 cm. long, 1.7-2.5 cm. wide, branches few, horizontal or at length strongly reflexed, spikelets elliptic, acute at both ends, glabrous, barely 1 mm. long, pedicels divaricate, first scale ovate, acute, scarcely one-fourth as long as the thin faintly 7-nerved second and third.

Panicum parvipaniculatum is related to *P. lucidum* from which it is separated by having somewhat smaller spikelets, smaller leaves and glabrous sheaths, and an erect habit. It begins to flower about two weeks earlier than *C. lucidum*. Collected May 20, in Onslow county, N. C. Type material is preserved in my herbarium.

Panicum pauciciliatum n. sp. A perennial forming small or large tufts. Culms 2-3 dm. long, rising from a geniculate base or reclining, at first simple at length much branched, reddish or purplish, slender, glabrous or the lower internodes puberulent. Stem leaves 3-4, lanceolate, 2-5 cm. long, 4-6 mm. wide, spreading or ascending: glabrous or with a few

stiff white cilia on the margin near the base : sheaths somewhat loose, often purplish, the lower less than one-half the length of the internodes : ligule none. Panicle 3-7 cm. long, broadly oval, the few branches spreading : spikelets 1.5 mm. long, obovate, obtuse, contracted at the base, the first scale very obtuse, nearly orbicular, about one-third the length of the nearly glabrous obtuse second and third.

This species is closely related to *P. demissum*, from which it is separated by having smaller and more numerous spikelets. Collected by me May 20, 1899, growing in dry sand near Wilmington, N. C.

PANICUM ONSLOWENSE n. sp. A perennial growing in small tufts. Stems 2.5-3.5 cm. high, erect or rising from a geniculate base, glabrous. Stem leaves 3-5, 2-4 cm. long, 3-5 mm. wide, lanceolate, narrowed at the base, the upper reduced in size, erect or ascending, glabrous except a few short 2-3 mm. long cilia on the margin at the base, the edges white and roughened : basal leaves much longer and broader, sometimes 6 cm. long and 1 cm. wide : ligule none : sheaths glabrous, sheaths with the leaves shorter than the internodes. Panicle broadly ovate, 4-6 cm. long : branches few, fascicled, spreading very rough : peduncle 1-2 times the length of the panicle : spikelets very short-pedicled, elliptic, acute at both ends, 2-2.5 mm. long, the very thin obtuse first scale one-third to one-half the length of the strongly 7-nerved glabrous second and third.

Panicum Onslowense occurs in the flat woods and savannas near the coast in the southeastern part of North Carolina and the adjacent parts of South Carolina. It is not uncommon in the eastern part of Onslow county, N. C., where the type material was collected near Ward's Mill. It is related to *P. Nashianum* and *P. demissum*, from both of which it is separated by having acute spikelets and an erect habit.

PANICUM FILIRAMUM n. sp. A perennial with 2-5 stems from the same root. Stems very slender, simple, ascending or spreading, at length much branched and reclining, 4-7 dm. long, pubescent at least below with short spreading or ascending hairs about 2 mm. long. Stem leaves 2-6 cm. long,

2-4 mm. wide, the upper very short, rather thin, narrowed at the base, ascending, pubescent especially on the lower surface and towards the base with spreading hairs, or glabrous: ligule villous with white hairs 3 mm. long: sheaths pubescent with spreading or ascending hairs 1-2 mm. long, especially at the throat: nodes barbed: basal leaves glabrate, much broader and shorter than the lower stem leaves. Panicle 4-6 dm. long, oval, the branches horizontal, glabrous: spikelets numerous, on very slender spreading pedicels, broadly obovate, 1.5 mm. long, first scale very obtuse, about one-third the length of the pubescent 5-7 nerved second and third.

This species is related to *P. arenicolum* and *P. arenicoloides*, but is separated from both by having very much smaller spikelets. Habitat: sandy woods, eastern North Carolina. Type material collected in New Hanover county, N. C., in June 1899.

PANICUM ARENICOLOIDES n. sp. A perennial with 2-5 stems from the same root. Stems very slender, simple, ascending from a geniculate base, or at length much branched and spreading, 4-7 dm. long, pubescent, at least below, with 3-4 mm. long spreading white hairs, or merely puberulent, glabrate above. Stem leaves 5-8, spreading or ascending, 4-11 cm. long, 2-4 mm. wide, narrowed at the base, pubescent, especially near the base, with 3-4 mm. long spreading white hairs, or glabrate, the longest one-third above base of stem, upper much narrowed and shorter: basal leaves much broader and shorter: ligule of dense white hairs about 1 mm. long: sheaths one-third to one-half the length of the internodes, which are generally somewhat longer than the leaves, pubescent, especially the lower, or glabrate. Panicle 5-7 cm. long, 2-5 cm. wide, the rather few flexuous branches erect or ascending: spikelets obovate, 2-2.2 mm. long, abruptly acute, contracted at the base, first scale acute, one-third the length of the strongly 7-nerved very pubescent second and third: peduncle about the length of the panicle.

Habitat: shady sandy woods along the coast of North Carolina. Type material collected by me near Wilmington, N. C., June 6, 1899. This species is intermediate in many

ways between *P. arenicolum* and *P. neuranthum*. The very long narrow stem leaves and the pubescence of the plant are distinctive, however.

PANICUM ORTHOPHYLLUM n. sp. A somewhat tufted perennial. Stems strict, erect, glabrous, or pubescent with ascending hairs, 4-6 dm. high, primary stem leaves somewhat narrowed to the base, erect, glabrous or nearly so, 5-8 cm. long, 3-5 mm. wide: sheaths appressed pubescent or glabrous with a few cilia near the throat, shorter than the internodes, or the later crowded and overlapping: secondary leaves much narrower: ligule a ring of hairs 1-2 mm. long: basal leaves few, much shorter and broader. Panicle long-peduncled, ovate, the few branches erect, ascending or spreading, glabrous: spikelets barely 2 mm. long, broadly obovate, very obtuse, first scale small, obtuse, about one-fourth the length of the sparingly pubescent strongly 7-nerved second and third.

Shady slopes of sand hills, New Hanover county, N. C., June 1899. Related to *P. angustifolium* and *P. neuranthum*, from which separated by having smaller obovate spikelets.

PANICUM ERYTHROCARPON n. sp. A somewhat tufted perennial. Stem stout, erect, 4-6 dm. high, pubescent, at least below, with soft appressed or ascending hairs. Primary stem-leaves spreading or erect, 4-7 cm. long, 4-8 mm. wide, lanceolate, rounded or narrowed at the base, long taper-pointed, pubescent on both sides with appressed hairs, often mixed with long spreading hairs towards the base on the upper side, margins ciliate at the base: ligule pilose: sheaths appressed pubescent, often nearly as long as the internodes. Panicle 7-12 cm. long, 6-14 cm. wide, on a peduncle of about its length, the numerous fascicled branches spreading or drooping. Spikelets 2.5-3 mm. long, elliptic, acute, generally bright red, the first scale very acute, nearly one half as long as the pubescent 7-nerved second and third.

This plant is separated from *P. pubescens*, which it resembles, by having larger spikelets and ascending pubescence, and from *P. haemacarpum* by having larger spikelets, a more ample panicle, and much greater size.

The type material was collected by the writer on the sand hills of New Hanover county, N. C., May 19, 1899.

PANICUM MISSISSIPPIENSE n. sp. A tufted perennial 3-4 dm. high. Stems erect, glabrous or nearly so, often papillate below, at first simple, at length branched especially from the lower nodes. Primary stem leaves 3-7 cm. long, 3-7 mm. wide, rounded at the sparingly ciliate base, otherwise glabrous, rough on the margin: ligule a mere margin: sheaths much shorter than the internodes, papillate, glabrous except the edge which is finely ciliate with hairs 1-2 mm. long: basal leaves few and short. Panicle oblong, 3-5 cm. long, glabrous, on a peduncle 2-3 times its length, the mostly single branches short and horizontal: spikelets glabrous, nearly orbicular, 1.2 mm. long, 1 mm. wide, the nearly orbicular first scale, one-third the length of the very thin faintly 5-nerved, glabrous second and third: later panicles exerted on short peduncles.

A very distinct species. Collected by me on the banks of the Mississippi river below New Orleans in October. I also refer here S. M. Tracy's No. 6777, collected on Horne Island, Miss., in July 1899.

PANICUM TAXODIORUM n. sp. A very slender perennial, 4-7 dm. high, at first simple and erect, at length spreading and loosely branched. Leaves very thin, glabrous, dark green, the edges very rough, 4-10 long, 3-5 mm. wide, narrowly lanceolate, narrowed to the scarcely rounded base, long taper-pointed: ligule none: sheaths glabrous except the finely ciliate margins, or with a few long hairs at the throat: basal leaves, in the specimen at hand very short, and few. Panicle 6-10 cm. long, ovate, the branches few, slender, fascicled, ascending: spikelets full 2 mm. long, elliptic or obovate, acute, glabrous, short-pedicled.

This species is related to *P. dichotomum* but differs in the panicle having fewer, ascending branches, acuter spikelets, narrower leaves, and in having the secondary panicles exerted.

Type: K. K. McKenzie's No. 460. Hummocks in cypress swamps. Lake Charles, La., September 1890.

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SEVENTEENTH YEAR—PART FIRST

1900

THE LABORATORY OF THE U. S. FISH COM-
MISSION, AT BEAUFORT, N. C.

H. V. WILSON.

Extracted with permission from the report for 1899 of the U. S. Commissioner of Fish and Fisheries, Hon. Geo. M. Bowers.

In conjunction with the fresh-water fish-cultural operations carried on at its new station at Edenton, N. C., on Albemarle Sound, the Commission contemplates the artificial propagation of the important salt-water fishes which spawn in the coastal waters of North Carolina and other South Atlantic States. An essential preliminary to this work is the study of the habits, abundance and distribution of the food-fishes, and also the determination of the non-economic fishes and other animals which are related to the food-fishes as food, enemies, etc. After consultation with Prof. J. A. Holmes, of the North Carolina Geological and Natural History Survey, Dr. H. V. Wilson, Professor of Biology in the State University, and other

persons interested in the development of the fishery resources of the region, it was decided that the best place for the prosecution of marine fish-cultural operations and the conjoint scientific investigations was Beaufort harbor. The harbor and the adjacent waters teem with animals in great variety and abundance. Many naturalists have from time to time resorted to the region for the study of special problems, the advantages of the locality having been especially demonstrated by Professor Brooks and other members of Johns Hopkins University, who maintained a laboratory at Beaufort during a period of ten years.

The consensus of opinion was that the Beaufort region was not only favorable for the study of the comparatively local problems of the North Carolina waters, but also for the investigation of the fauna of the southeastern coast in general, from the combined economic and scientific standpoints. Accordingly, in May, 1899, the Commission announced that it would maintain, during the succeeding summer, at Beaufort, N. C., a laboratory for the study of questions pertaining to fish-culture, fisheries and marine biology, and placed Prof. H. V. Wilson in charge. Beaufort is situated on Beaufort Harbor, near one of the great ocean inlets, and is reached by boat from Morehead City, the nearest railroad terminus. The use of a commodious building on the water front was acquired at a nominal rental; a suitable equipment was provided; a small working library was installed; a steam launch was assigned from another station, and on June 1 the laboratory was opened to a limited number of investigators. By the close of the year the following persons had taken tables in the laboratory, and a number of others had applied for accommodations later in the season: Dr. D. S. Johnson, Dr. Gilman A. Drew, Dr. Caswell Grave and Mr. W. C. Coker, all of Johns Hopkins University; Prof.

J. I. Hamaker, of Trinity College, N. C.; Prof. T. G. Pearson, of Guilford College, N. C.; Prof. E. W. Berger, of Baldwin University, Ohio, and Prof. H. V. Wilson, of the University of North Carolina.

The special investigations carried on at the laboratory in June included the following: Dr. Johnson and Mr. Coker studied from a systematic and œcological standpoint the marine algae of the harbor and the flora of the banks. Dr. Drew considered the habits of the clam (*Solenomya velum*), investigated the breeding condition of the round clams (*Venus mercenaria* and *V. elevata*) and other bivalve mollusks, and reared the eggs of *Venus elevata*. Dr. Grave studied the embryology of certain ophiurans, and made a number of valuable observations on the breeding time and general life-history of other echinoderms. Professor Wilson's work included observations on the breeding condition of the sponges and of certain edible fish. All the members of the laboratory cooperated in the effort to determine the animals and plants in and near the harbor, their abundance, local distribution, breeding times, habits, etc. The foundation of a museum collection illustrating the fauna and flora of the region was laid, and a record book was opened, in which full notes on each species observed were entered.

[Reprinted from *Science*.]

The second session of the Beaufort Laboratory of the U. S. Fish Commission came to an end September 15th, 1900. The occupants of tables were from Johns Hopkins University, Columbia University, University of North Carolina, and Trinity College (N. C.). The economic work, carried on by special assistants in the service of the Commission, embraced a study of the neighboring natural and artificial oyster beds, breeding times and food of certain food-fishes, life histories of fish (blennies), life

history of a lepadide barnacle (*Dichelapsis*) which has been found to be a common parasite in the gill chambers of the edible crabs, *Callinectes* and *Menippe*. The more purely scientific investigations covered a wide field, embracing such diverse subjects as the systematic zoology and ecology of actinians, echinoderms, and sponges; embryology of ophiurans; larval development of actinians; regeneration phenomena in ophiurans, and in *Renilla*; embryology of geophyrean worms (*Thalassema*); cell lineage of *Axiotea*; experimental work on the cleavage of the oyster egg; cytological phenomena in the "chemically fertilized" eggs of *Toxopneustes*.

SOME EAST AMERICAN SPECIES OF CRATAEGUS.

CONTRIBUTIONS FROM MY HERBARIUM, NO. X.*

W. W. ASHE.

CRATAEGUS RORIBACCA sp. nov. A small tree, 4-7 m. in height, with an oval crown and spreading or ascending branches, the trunk generally furrowed or fluted, its dark gray bark broken into thin scales, the bark of the branches light gray. Twigs, slender, glabrous, armed with very few 3-5 cm. long thorns. Leaves thin, flaccid, bright green, glabrous below, somewhat scabrous above, the blades broadly ovate or nearly orbicular, often isodimetric, 4-8 cm. long, 3.5-7 cm. wide, very sharply serrate except at the base, seldom doubly serrate or lobed except on vigorous shoots, and such lobes very shallow, abruptly acute at apex, rounded, truncate or subcordate at base; petiole slender, 2-3.5 cm. long. Corymbs compound, 8-20-flowered, 5-8 cm. wide, glabrous; stamens 20; fruiting pedicels 1-5, 1-4 cm. long, spreading or drooping. Fruit

*Issued Dec. 20, 1900.

globular, generally thicker than long, 11-14 mm. long, 14-17 mm. thick, dark, but bright red, or occasionally with orange-red or orange spots, flesh pale yellow; calyx lobes sessile or nearly so, the cavity 4 mm. wide; seed large, 7-8 mm. long, about 4 mm. wide, the lateral faces plane, deeply dorsally sulcate.

I have seen this tree only on Oconaluftee river, in the mountains of North Carolina, where the type material was collected.

CRATAEGUS RUGOSA, sp. nov. A small tree, 3-4 m. in height, with an oval or flattened crown and horizontal or spreading branches and dense foliage. Twigs glabrous, slender, geniculate or flexuous, armed with stout 4-6 cm. long thorns. Leaves glabrous, thin but firm, light green above, yellowish beneath, the blades broadly ovate or deltoid, often isodimetric, obtuse or truncate at base and generally shallow-lobed, much wrinkled; petiole slender, 1-2 cm. long, about one-half the length of the blade. Corymbs glabrous, simple or nearly so, 4-8 flowered, 4-5 cm. wide, fruiting pedicels 1-2 cm. long; calyx broadly conical, the short 3-5 mm. long entire lobes narrowly triangular; stamens 20, 5 mm. long; fruit globose, glabrous, 9-14 mm. thick, dull red or reddish when ripe, and capped by the persistent calyx lobes, pruinose; seed 5-6 mm. long, the lateral faces plane.

Roadsides and old fields, Ashe and Watauga counties, North Carolina, and northward.

CRATAEGUS ARENICOLA sp. nov. A slender tree, with few irregular branches, or generally a shrub. Twig of the season slender, chestnut brown, villous with short coarse grey hairs; thorns very slender, 3-4 cm. long, generally grey. Leaves thin but firm, dark green, lucid and rough above, much paler, dull and rough pubescent beneath, ovate, obovate, or spatulate, 2-5 cm. long, 1.5-3 cm. wide, obtuse or rounded at the apex, dentate, except

at the entire base where narrowed into the short, 5 mm. long, margined petiole. Corymbs simple, 1-5 flowered, pedicels erect, villous, 3-7 mm. long; calyx pubescent, stalked and persistent on the fruit, the lobes lanceolate, 6 mm. long, laciniate, persistent; petals white, nearly orbicular, about 7 mm. long; stamens 20, barely 2 mm. long. Fruit pyriform, 12 mm. long, 8-10 mm. wide, villous when young, at length glabrate, orange, or red-cheeked when ripe; falling in October before the leaves.

Type locality, Jessup, Moore county, N. C. *Crataegus arenicola* is not uncommon throughout the coastal plain. It is related to *C. Raleighensis*, from which it is separated by the differently shaped crenate leaves, and more pyriform, shorter pedicelled fruit.

CRATAEGUS BREVIPEDICELLATA sp. nov. A small tree 2-4 m. in height, with an open crown of a few short spreading branches. Twigs slender, glabrous, geniculate, those of the season a bright glossy red or purple brown; thorns slender, 3-4 cm. long, usually straight. Leaves thick, firm, yellowish green, rather dull, the blades obovate or nearly orbicular in outline, 2-4 cm. long, 1.5-4 cm. wide, finely and obtusely glandular serrate, occasionally with 3-5 shallow lobes, obtuse, rounded or acute at apex, narrowed at the acute or rounded base into a stout margined glandular roughened petiole, about 1 cm. long. Corymb simple, 3-6-flowered, pedicels glabrous, rather slender, 7-13 mm. long while in flower, with one or two early caducous, glandular, margined viscid bractlets; calyx deeply conical, stalked on the fruit and at length generally deciduous, the lobes oblong, glandular serrate; stamens 10. Fruit glabrous, orange red or dull red, the flesh orange; seed 4-5, the lateral faces plane.

Type locality, near Priest Hill, Moore county, N. C.

CRATAEGUS CATAWBIENSIS sp. nov. A small tree

4-6 m. in height, with an oval crown, and spreading or ascending branches. Twigs very slender, glabrous, sparingly armed with stout thorns 3-5 cm. long. Leaves glabrous, thin but firm, dark green above, paler beneath, the blades ovate or broadly ovate 3-6 cm. long, 2.5-5 cm. wide, sharply and coarsely serrate, and with a few shallow lobes, acute at apex, rounded or truncate at base; petiole 1.6-3 cm. long, about one-half the length of the blades. Corymbs glabrous, compound, generally becoming simple in fruit, 4-6 cm. wide, 3-7-flowered. Fruit obovate or nearly globular, 13-16 mm. long, 12-15 mm. thick, dull dark red when ripe, mottled with green or orange, maturing early in October and persistent until after the leaves fall; pedicels 1-1.6 cm. long, ascending or spreading; calyx nearly sessile on the fruit, the short triangular lobes spreading; stamens 20; seed generally 5, apical, 7-8 mm. long, lateral faces plane, 4-5 mm. wide, dorsal furrows shallow; flesh firm and juicy, whitish.

Headwaters of the Catawba river. Type material from near Round Knob, McDowell county, N. C.

CRATAEGUS MULTISPINA sp. nov. A small tree 2-4 m. in height, with numerous horizontal straight branches, which form a flattened or globular crown, and dense foliage. Twigs slender, glabrous, brown-purple, armed with numerous thorns, 2.5-4 cm. long. Leaves glabrous, coriaceous, lucid, firm, bright green above, paler beneath, spathulate, 2.5-4.5 cm. long, 7-16 mm. wide, rounded at apex, gradually tapering below into a short petiole or sessile, denticulate above, entire below the middle. Corymbes glabrous, very compound, 5-8 cm. wide, 10-20-flowered; flowers small, about 1.5 cm. wide; stamens 5-10; calyx lobes very narrowly triangular, acute, entire, sessile and persistent on the mature fruit. Fruit oblong, 9-12 mm. long, 7-9 mm. thick, dull red brown when ripe, in large clusters, on slender drooping pedicels 7-20 mm. long; seed generally 5, small, the lateral faces plane.

Dry hillsides, McDowell county, N. C., between 400 and 900 m. altitude. The type material from Round Knob, below Swannanoa Gap, is preserved in my herbarium. This species is very much like *Crataegus crus-galli*, but both leaves and fruit are much smaller, and the foliage is a darker green.

CRATAEGUS SCHNECKI sp. nov. A small tree, with drooping branches. Twigs very slender, purplish or brown-purple. Leaf-blades 3-7 cm. long, 2-6 cm. wide, ovate, broadly ovate or nearly orbicular in outline, thin and glabrous, bright green, truncate, obtuse or rounded at base, sharply serrate; petioles slender, winged above, 1-4 cm. long. Inflorescence wide-spreading, nearly simple, 4-8 flowered; stamens 20; styles 4-5; fruit nearly globular, about 8 cm. thick, bright red when mature, sparingly glaucous, tipped by the persistent greenish calyx-lobes which are acute and entire; pedicels 2.5-4 cm. long, slender, glabrous.

Collected at Lawrenceville, Ill., in 1895, by Dr. J. Schneck, with whose name I am pleased to associate the *sagoido*.

CRATAEGUS HAEMACARPA sp. nov. A tree 5-8 m. in height, with numerous long ascending branches forming an oblong or oval crown, the short branchlets racemose along the branches. Twigs glabrous, slender, armed with numerous slender, 3-4 cm. long, dark purple-brown thorns. Leaves thin but firm, glabrous, erect or ascending on strict petioles, persistent until late in autumn and coloring a brilliant scarlet; the blades broadly ovate or deltoid, 2.5-5 cm. long, 2.5-6 cm. wide, rounded, truncate or on vigorous shoots cordate at the serrate base, sharply and rather coarsely serrate or doubly serrate, on vigorous shoots 3-5 lobed; petioles 1.5-2.5 cm. long, very narrowly margined, sometimes roughened with a few dark glands. Inflorescence a 4-11-

flowered, nearly simple corymb, 3-6 cm. wide; stamens 20. Fruit in simple 2-5-rayed cymes, on slender, 2-3 cm. long, ascending or spreading pedicels, depressed pyriform, generally much broader than long, 8-12 mm. long, 10-14 thick, angled by the nutlets, glabrous, very dark purple, olivaceous or at length bright crimson, pruinose, ripening late in October and persistent until late in winter after the foliage has fallen, capped by the sessile calyx, its narrowly triangular lobes erect and coloring with the fruit; flesh firm, juicy, becoming blood-red as the fruit colors; nutlets 3-4, small, 5 mm. long, the lateral faces plane, very deeply sulcate and ribbed on the back, placed nearly central in the fruit.

The type material is from the banks of the Cullasagee river, Macon county, N. C., where the species is very abundant. This tree is evidently closely related to *Crataegus macrosperma*, from which it is separated by the smaller nutlets, and smaller and differently shaped fruit, which persists after the fall of the foliage.

CRATAEGUS FLAVO-CARNIS sp. nov. A slender tree 3-5 m. in height, with short intricate branches forming an oblong crown, the bark of the trunk nearly black, cross-checked, as of the black haw, that of the branches dark gray. Twigs slender, glabrous, purple-brown; armed with numerous, 3-4 cm. long stout thorns. Leaves glabrous, thick and firm, very dark green above, pale beneath, the blades 3-5 cm. long, 2-4 cm. wide, ovate, obovate or nearly orbicular in outline, acute or obtuse at the apex, rounded or cuneate at the serrulate base, obtusely serrate; petiole .6-2 cm. long, margined above, and roughened by 1-3 pairs of dark brown glands. Inflorescence a usually simple corymb, glabrous, 3-6 cm. wide, 3-8-flowered; pedicels ascending (even in fruit), 1-1.8 cm. long; stamens 10; calyx-lobes large, oblong glandular serrate, Fruit globular, 12-14 mm. thick, somewhat angled by the

nutlets, bright red or orange-red when ripe in October, capped by the short-stalked calyx, its lobes spreading; flesh orange-yellow; nutlets apical, 4-5, 6-7 mm. long, deeply furrowed dorsally, the lateral faces plane.

Type material from near Salisbury, N. C. This species is related to *C. rotundifolia*, from which it is easily separated by the shape and texture of the leaves and the different fruit.

CRATAEGUS PEARSONI sp. nov. A small tree 5-8 m. in height with dark brown or blackish rough bark, and tortuous branches forming an oval crown. Twigs flexuous or geniculate, slender, at first canescent, at length glabrous and glossy red-brown, armed with numerous stout, short, thorns. Leaves, when young, more or less canescent on both sides, at length nearly glabrous, spathulate or obovate, 3-6 cm. long, rounded at the apex, cuneate at the base, the margins glandular-crenate and often 3-5 notched at the apex; petiole 1-2 cm. long, glandular roughened. Inflorescence cymose, 3-7-flowered, 5-6 cm. wide, pedicels 2-3 cm. long, canescent, at length glabrate; flowers 2-2.5 cm. wide; stamens 20; calyx-lobes very long, 6-8 cm. long, ligulate, serrate at the end. Fruit oblong, 11-16 mm. long, dark red when ripe, and capped by the nearly sessile calyx; cavity 6-7 mm. wide; flesh orange; nutlets 4-5, 7-8 mm. long, attenuate at base, lateral faces plane, dorsal surface nearly smooth.

Type material from Kings Mountain, N. C. Related to *Crataegus elliptica*, from which separated by having larger fruit and differently shaped foliage. Named for Prof. Gilbert Pearson, of Guilford College, N. C.

CRATAEGUS CULLASAGENSIS sp. nov. A small tree 4-8 m. in height with dark brown or blackish bark broken into small rectangular scales, and long spreading or drooping branches forming an oval crown. Twigs slender, flexuous or nearly straight, glossy purple-brown,

when young sparingly pubescent, armed with numerous stout 3-4 cm. long thorns. Leaves thin but firm, bright green, glabrous above, at length glabrous below, with 3-4 pairs of prominent veins, the blades ovate rhombic or obovate, 2.5-5 cm. long, 1.5-4 cm. wide, cuneate at base, obtuse or rounded at apex, 3-5 notched above the middle, glandular denticulate; petiole 5-2.5 cm. long, narrowly margined or winged above by the decurrent blade, roughened by numerous sessile dark brown glands. Inflorescence in nearly simple corymbs, sparingly pubescent, at length glabrate, 3-7-flowered, 4-6 cm. wide; calyx-lobes narrowly triangular or ligulate, 5-7 mm. long, glandular-serrate, persistent on the fruit; stamens 20, very slender. Fruit glabular or slightly oblong, 12-16 mm. thick, soon glabrous, dark orange mottled with orange-red and crimson, persistent after ripening on ascending or spreading pedicels until after the leaves have fallen, capped by the persistent stalked calyx; the 5 mm. wide cavity obconic; flesh orange, firm and dry, very sweet; nutlets 4-2, 6-7 mm. long, the lateral faces plane, the back nearly smooth.

The type material is from hills along the Cullasagee river, Macon county, N. C. This species is related to *C. Michauxi* and also to *C. flava*. It is separated from *C. Michauxi* by having much larger fruit and smaller leaves; and from *C. flava* by having thinner, more pointed leaves and geniculate twigs.

CRATAEGUS RIPARIA sp. nov.. A small tree 4-10 m. in height with dark bark broken into small thin scales, and spreading or ascending branches which form a dense oval crown. Twigs glabrous, somewhat flexuous on vigorous shoots. Leaves thin, glabrous, the blades ovate or deltoid, or nearly orbicular, 4-7 cm. long, 3-6 cm. wide truncate or rounded at base, abruptly acute at apex, sharply serrate, 7-9-notched; petiole slender, 2-3 cm.

long. Flowers in 5-10-flowered compound glabrous, 4-6 cm. wide, corymbs; stamens 10. Fruit globular 14-17 mm. thick, bright orange-red or darker, capped by the very closely sessile calyx, the lobes erect; flesh yellow; nutlets 7-8 mm. long, prominently ridged dorsally, lateral faces plane; fruiting pedicles 5-13 mm. long, spreading or declined.

Type material from Swain county, N. C., where the species is very common along the Oconaluftee river.

CRATAEGUS DURIFOLIA sp. nov. A small tree 4-6m. in height with slender glabrous red-brown twigs sparingly armed with 3-4 cm. long thorns. Leaves glabrous, thin, but firm, dark green above, paler and sparingly glaucous beneath, the blades rhombic or rhombic ovate in outline, 3-7cm. long, 2.5-6 cm. wide, with 2-4 pairs of prominent veins, finely and sharply serrate or doubly serrate or with 3-7 shallow lobes, acute at apex, cuneate or rounded at base; pedicels slender, more than one-half the length of the blades. Inflorescence cymose, 3-6 cm. wide, 3-8-flowered, glabrous; stamens 20; calyx-lobes stalked on the fruit, usually deciduous before it ripens; calyx-lobes narrowly triangular; the cavity 4-5mm wide. Fruit 8-10 mm. thick, globular, glabrous, dull red, persisting until after the foliage falls.

Alluvial lands on streams Missouri and Illinois. The type material is from Missouri. This species is closely related to *Crataegus Schneeki*, from which it is separated by having smaller fruit and smaller and differently shaped foliage.

CRATAEGUS GATTINGERI sp. nov. Twigs glabrous, dark purple-brown, sparingly glaucous, armed with numerous thorns 3-4 cm. long. Leaves glabrous, dark green above, paler beneath, the blades oblong, ovate or deltoid in outline, 2-7 cm. long, 2-5 cm. wide, rounded, truncate or subcordate at the base, attenuate at the apex.

finely, but acuminate serrate, generally with 3-5 prominent lobes; petiole slender, roughened above with 1-2 pairs of glands. Corymbs few-flowered, the pedicels slender and glabrous, 1-1.5 cm. long; calyx-lobes short, triangular, glabrous; stamens 20. Fruit dark red, sparingly pruinose, globular, 8-11 mm. thick, generally capped by the stalked, calyx-lobes persistent until after the foliage has fallen.

This species is probably nearest related to *Crataegus erythrocarpa* of the Atlantic coast, from which it is separated by the entirely different foliage and somewhat larger and more fleshy fruit. The type locality is Nashville, Tennessee, where the species was collected by Dr. Gattinger in September, 1880.

CRATAEGUS PALUSTRIS sp. nov. A small tree 5-8 m. in height. Twigs slender, glabrous, dark purple, at first sparingly glaucous. Leaf-blades ovate, 4-8 cm. wide, rounded, truncate or subcordate at base, acute at apex, finely and obtusely serrate, or doubly serrate, more or less 5-9 lobed, glabrous, firm and thick, dark green above, very pale beneath; petiole slender, 1-3 cm. long. Corymbs nearly simple, 3-5 cm. wide, glabrous 4-8 flowered; stamens 20; styles 4-5; calyx-lobes stalked, in fruit generally deciduous, the lobes very broad; the cavity 4-5 mm. wide, very shallow. Fruit glabrous, 9-14 mm. thick, nearly glabular, dark red; pedicels 1.5-3 cm. long.

Type material collected by the writer in a small alluvial swamp near Freeport, Indiana.

CRATAEGUS CILIATA sp. nov. A small tree 4-7 m. in height, with an oval crown of spreading or ascending branches. Twigs, glossy brown-purple, sparingly glaucous, when young somewhat villous, at length glabrate, armed with very slender dark purple thorns, 5-7 cm. long, or occasionally much shorter. Leaves dark green and scabrous above, paler beneath, more or less pubes-

sent along the prominent veins, the blades ovate or broadly ovate in outline, 3-5 cm. long, 2-3.5 cm. wide, acute at the apex, rounded, obtuse or truncate at the base, acuminate-serrate except at the entire base, often with 3-7 shallow lobes; petiole slender, 1.2-2.5 cm. long, pubescent with spreading hairs or ciliate on the lower side. Inflorescence cymose, 3.5-5 cm. wide, 4-7-flowered, the flowers appearing when the leaves are nearly fully grown; floral bractlets filiform, not conspicuous; pedicels 1-2.3 cm. long, at first sparingly pubescent, at length glabrate, strict; calyx ovate, the entire lobes broad and foliaceous; stamens 20. Fruit 9-12 mm. long, 8-11 mm. thick, dull red when ripe, sparingly pruinose, capped by the sessile calyx-lobes, the cavity 4-5 mm. wide, very shallow.

Dry hills, middle North Carolina to Pennsylvania. The type material is from Raleigh, N. C.

CRATAEGUS DISPERMA sp. nov. A slender tree 5-8 m. in height with gray or blackish scaly bark beset with numerous simple or compound thorns and fastigate branches forming an oval or obovate crown. Twigs slender, glabrous, dull brown or glossy red-brown, armed with numerous slender slightly curved 3-4 cm. long thorns. Leaves glabrous dark green, and glossy above, dull and much paler beneath; the blades ovate, elliptic or obovate, 4-7 cm. long, 3-5 cm. wide, obtusely serrate, sparingly and irregularly lobed, obtuse or abruptly acute at apex, rounded or acutely narrowed at base into the short .6-2.5 cm. long margined petiole. The flowers appear when the leaves are about half grown, in nearly simple 3-8-flowered corymbs, the short pedicels with 1-2 linear or oblong bright purple pectinately glandular caducous bractlets. Flowers white, 2 cm. wide; stamens 10, 6-8 mm. long; styles usually 2, slender, 5 mm. long; calyx obconic, the narrowly triangular divisions generally entire. Fruit oblong, 12-14 mm. long, 9-11 mm. thick, bright

but dark red, mottled with green, the calyx-lobes nearly sessile, the persistent lobes spreading; fruiting pedicels erect or ascending, .6-1.8 cm. long; seed usually 2, apical, 6-7 mm. long, dorsal grooves shallow, the lateral faces plane.

Pennsylvania and New York westward to Illinois. Type material from Wilkesbarre Mountain, Penn.

CRATAEGUS EGANI sp. nov. A small tree with spreading branches. Twigs slender, glabrous, armed with rather few short 2-4 cm. long thorns. Leaves glabrous, dark green above, paler beneath, the blades ovate in outline, 3-6 cm. long, 2-5 cm. wide, acuminate or abruptly acute at apex, rounded or obtuse at base, with 4-6 pairs of prominent parallel veins, sharply and finely serrate or doubly serrate all around, generally 5-9-notched; petioles slender, 2-3 cm. long. Inflorescence in glabrous compound 4-7 cm. wide, many flowered corymbs; flowers about 2 cm. wide; calyx-lobes 5-6 mm. long, narrowly triangular. Fruit bright red, glabrous, oblong; 12-16 mm. long, 8-13 mm. thick, capped by the sessile calyx-lobes, maturing about the middle of October, and persistent until after the leaves have fallen, in usually compound clusters, the 1-3 cm. long pedicels drooping; nutlets 3-4, small, 4-6 mm. long, the lateral faces 3 mm. wide, plane, the back smooth or with shallow furrows.

The type material, from northern Illinois, is preserved in my herbarium. *Crataegus Egani* is evidently related to *Crataegus Holmesiana* from which it is separated by having smaller foliage and fruit, and smaller nutlets. This species is named for Mr. W. C. Egan, of Chicago, Ill.

CRATAEGUS CUTHBERTI sp. nov. A small tree 3-5 m. in height with an open crown of few long tortuous spreading or pendant branches. Twigs rather stout, villos, at least when young, dull gray or brownish, geniculate, armed with stout 4-6 cm. long thorns. Leaves

dark green, thick, villous beneath with soft matted gray pubescence, at least when young, spathulate to orbicular in outline, 2-5 cm. long, .6-2 cm. wide, rounded, obtuse or acute at the apex, often 3-5-notched above, cuneate at base, the margin glandular-denticulate or serrate; sessile or with a short glandular petiole. The 10-13 mm. wide flowers appear when the leaves are nearly fully grown in 2-5-flowered cymes; calyx-lobes very narrow, villous, denticulate; stamens 20; pedicels strict in fruit, villous. Fruit globular or pyriform, 9-12 mm. thick, dull red, capped by the base of the stalked calyx, the cavity short-cylindrical, very villous at base; flesh orange; nutlets 4-5, lateral faces plane, the back nearly smooth, somewhat attenuate at the base.

Dry sandy soils, eastern North Carolina and southward. Type material from Bladen county, N. C. Named for Mr. A. Cuthbert, of Augusta, Ga.

CRATAEGUS GENICULATA sp. nov. A shrub less than one meter in height, or occasionally a very small tree 3-4 m. in height with long tortuous branches, the lower drooping, and rimose black bark. Twigs very slender, geniculate or flexuous, the internodes very short, at first pubescent with rough gray hairs, at length glabrate and brown-purple, armed with very slender gray or purple thorns 1.5-3 cm. long. Leaves at first more or less gray pubescent (especially their petioles, and those on vigorous shoots), at length glabrate, bright green on both sides, spathulate or obovate, 1-3.5 cm. long, .5-cm. 2 wide, rounded or obtuse at the apex, cuneate at the entire base, glandular denticulate or serrate, often with 3-5 notches above (or on vigorous shoots nearly orbicular, and the margins acuminate glandular serrate); petioles very short and glandular roughened, or the leaves are sessile. Flowers 1-3 together, pedicels .5-1.5 cm. long, erect, villous, at length glabrate; calyx obconic, villous,

the narrow lobes glandular denticulate; stamens 20. Fruit pyriform, 8-14 mm. long, 7-12 mm. thick, lemon-yellow, orange or mottled with red, capped by the persistent short-stalked calyx-lobes, falling with the leaves about the middle of October, or shortly after; flesh orange, dry and firm; nutlets 4-5, 5-6 mm. long, attenuate at the base, the back smooth or nearly so, lateral faces plane.

Dry hills, middle North Carolina. While closely related to *Crataegus Michauxi* the above species is at once separated from it by its smaller size, smaller foliage and more simple inflorescence.

CRATAEGUS YADKINENSIS sp. nov. A small tree 4-10 m. in height with numerous branches forming an oval or round crown and dense foliage. Twigs straight or somewhat flexuous, armed with few slender 3-4 cm. long thorns, at first villous, at length usually glabrate and bright brown-purple. Leaves obovate or spatulate, the blades 1.5-3 cm. long, rounded at the apex, the base cuneate, glandular denticulate, except at the entire base, 2-3 pairs of prominent divergent veins, when young pubescent, at least on the veins, and glandular-viscid, (on vigorous shoots nearly orbicular, sparingly lobed, and rounded or truncate at base, often permanently pubescent); petiole 3-10 mm. long, pubescent, glandular dotted. Corymbs nearly simple, 2.5-3.5 cm. wide, 5-10 flowered; flowers 13-15 mm. wide, appearing when the leaves are nearly fully grown; stamens 20; fruit pyriform or subglobose, 7-11 mm. thick, tipped by the stalked calyx-lobes, dull red or orange when ripe in September.

The type material is from Rowan County, N. C. from the hills along the Yadkin river.

ON THE ADIE AND WOOD METHOD FOR THE DETERMINATION OF POTASSIUM.*

CHARLES BASKERVILLE AND ISAAC F. HARRIS.

The American Agricultural Chemists through their official organization have done most valuable work in improving, standardizing and shortening the methods for analysis of the products of husbandry. Refined and abbreviated volumetric methods are in use for nitrogen and phosphoric acid. Attention has been directed toward the shortening of the method for potash by the use of Gladding's solution and variations in detail.

The method of Adie and Wood (*J. L. Chem. Soc.* 77; 1078) founded upon the observations of Erdmann (*J. pr. Chem.* 77; 385) and Sadtler (*Amer. J. Sci.* 49; 189), namely, the formation of an insoluble double sodium and potassium cobaltinitrite, $[K_2NaCo(NO_2)_6, H_2O]$ promises an ideal and most satisfactory gravimetric and volumetric process. We have tested it in this laboratory on a commercial muriate with very good results:—

| | Official Method. | Adie and Wood Method. |
|--------------|------------------|-----------------------|
| Potash found | 48.63 per cent. | 49.02 per cent. |
| | | 48.72 " " |

Full details of the method are to be found in the original article (*loc. cit.*). The advantages of the method carried out according to the specific directions may be summed up as follows:—precipitation directly from the filtered digestion of the fertilizer or soil; avoidance of the use of expensive platinic chloride; the precipitant, sodium cobaltinitrite, is easily prepared and and keeps well; great saving of time, as determination can be made within two hours.

*Read at the Fall Meeting of the N. C. Section of the American Chemical Society. Nov. 9th. 1900.

RICHTER AND THE PERIODIC SYSTEM.

F. P. VENABLE.

A very remarkable work appeared at the close of the last century. This was 'Die Anfangs-gründe der Stöchiometrie', by J. B. Richter, the first volume of which appeared in 1792, and the third and last volume in 1794. In this book we have the first definite statement of the law of proportionality, and some have thought that they have found in it also the Atomic Theory, though it is not claimed that this theory was definitely stated.

Richter's work attracted much attention at the time because of his defense in it of the phlogistic theory and it was vigorously attacked by the supporters of the New Chemistry, who followed Lavoisier and the French chemists. The deeper purport of the book and the new ideas advanced do not seem to have been well understood or to have been largely commented upon. Fischer, who in 1802 translated into German Berthollet's 'Statique Chimique,' was apparently the first to draw general attention to the work of Richter and to its bearing upon the conclusions drawn by Berthollet. This latter chemist and Guyton de Morveau acknowledged that Richter had anticipated them in the inference to be drawn from the permanence of neutrality after the decomposition of certain neutral salts and the possibility of calculating beforehand the composition of the salts produced. The discovery of the law of proportionality was a most important one and Richter must, therefore, be regarded as a very remarkable man. In his discovery that the amounts of different metals combining with a given weight of acid combine with a fixed amount of oxygen, he went a step further, anticipating the work of Gay Lussac, and when

he established the fact that such metals as iron and mercury have the power of combining with oxygen in several proportions, showing different degrees of oxidation, he was several years ahead of Proust and verged upon the discovery of the law of multiple proportions.

With all of his ability to see deeply into the workings of natural phenomena Richter was not a clear and logical thinker. Wurtz rightly speaks of him as 'the profound but perplexed author of the great discovery of proportionality.' He was confused by his adherence to the illogical phlogistic theories which were becoming each year more untenable. He was further hampered by his determination to give a mathematical foundation to the science of chemistry and to express all chemical changes by formulae and equations worked out along algebraic lines. It was doubtless, the presence of these mathematical equations all through his volumes which deterred many chemists from a full and patient examination of them for the kernel of truth which they might contain. The average experimental chemist is not much attracted by abstruse mathematical speculations.

Later chemists commenting upon his work have made some mention of the mathematical regularities observed by him and this led me to think that perhaps Richter might have caught some glimpse of the periodic law before the conception of the atom and the atomic theory had entered into chemistry. To investigate this question it was necessary to examine Richter's writings and I was fortunate enough to secure the use of a copy of his *Stöchiometrie* through the courtesy of the librarian of the American Academy of Arts and Sciences.

It is of interest, first, to see how near an approach Richter made to the conception of atoms. In the preface to volume I the question of solution is discussed and the statement is made that "the chemist cannot boast of

being able in any manner to divide a body up into the smallest parts because matter can be thought of as infinitely divisible." From many passages one may judge, however, that he held to the corpuscular view of matter, namely that it was composed of certain very small, discrete particles, which were, however, conceivably further divisible. Thus in giving the various definitions of elements he says that to one chemist the word meant the simplest indestructible substance, the subtlest material which the creator had created for the formation of all other bodies; to another it meant such materials as could not be decomposed into dissimilar particles and in which no component particles could be recognized. For himself he prefers to divorce the word from all connection with primal matter, or *Urstoffe*, and to make use of it simply as a part of the chemical technology, attaching to it the meaning of a body undecomposable by any means known to the chemists. Chemistry as an art, according to Richter, consisted in the ability to separate elements from one another and to bring them together as constituents of a new body. Chemistry as a science was something greater, including its theories and fundamental axioms. A chemical element, he says, is one which, without being decomposed into unlike parts, can by mixing with other kinds of matter cloak their peculiar characteristics and bring about others. It is *elementum immediatum* when it cannot be decomposed into unlike parts: *medium* when it can be thus decomposed (p. 5 seq.).

Thus, as Richter adds in a footnote, vitriolic acid is an *elementum immediatum* since no one has been able to decompose it into unlike parts, but sulphur is an *elementum medium* since anyone knows that it can be decomposed into vitriolic acid and phlogiston and reformed from these two. This is of interest as showing the degree of

knowledge on which he based his reasoning. His corpuscles are called 'Theilganzen,' and in these the force of affinity resides. Thus he states, "to each infinitely small particle of the mass of an element there belongs an infinitely small portion of the chemically-attracting force of affinity" (p. 123).

The part of Richter's work which appears to refer most nearly to the periodic system is found in his second volume on page VI of the preface. He refers to the fact that the supposition had already been made in a paper on the 'Newer Objects of Chemistry, especially the re-discovered half-metal Uranium,' that the affinities of many chemical elements towards any single one might be in a definite progression. The supposition, says Richter, has already in the case of four quantitative series been raised to the dignity of an incontrovertible rule. The tables of masses form arithmetical progressions and the affinities of the elements which belong to the series, proceed also, in so far as they are not disturbed by the indwelling elementary fire, in the order of the masses. Besides one is in position to see the probability of many homogeneous elements present in nature. Also the double affinities proceed in arithmetical progression and "with careful observations one can scarce resist the thought that *the entire chemical system consists of similar progressions.*"

It is well to examine a series given by Richter to get more fully at his meaning. Thus in the same volume, page 28, he gives the masses of the alkaline earths which neutralize 1,000 parts of hydrochloric acid.

Magnesia $734 = a$

Lime $858 = a + b$ ($734 + 124\frac{1}{2} = 858\frac{1}{2}$)

Alumina $1,107 = a + 3b$ ($734 + 3 \times 124\frac{1}{2} = 1,107\frac{1}{2}$)

$= a + 5b$ ($734 + 5 \times 124\frac{1}{2} = 1,356\frac{1}{2}$)

$= a + 7b$ ($734 + 7 \times 124\frac{1}{2} = 1,605\frac{1}{2}$), etc.

Baryta $3,099 = a + 19b$ ($734 + 19 \times 124\frac{1}{2} = 3,099\frac{1}{2}$)

Similar series are given for the alkalis and alkaline earths with the different acids. Again these tables are compared with one another and thus was brought out the law of proportionality. One of the most remarkable regularities is gotten by examining the differences in the masses in such a series made up of observed combining numbers of known elements and interpolated combining numbers of hypothetical elements. Thus (p. 38):

$$\begin{aligned} 616-526 &= 90 = 1 \times 90 \\ 796-529 &= 376 = 3 \times 90 \\ 973-526 &= 347 = 5 \times 90 - 3 \\ 1,152-526 &= 626 = 7 \times 90 - 4 \\ 1,330-526 &= 804 = 9 \times 90 - 6 \\ &\text{etc., etc.} \end{aligned}$$

Of course, it is readily seen that all these regularities are more in the line of the triads of Döbereiner or the later work of Dumas than the periodic system. But a close examination reveals something more—a really deeper insight into the nature of the elements which is marvellous when one considers that Richter was dealing with compounds not elements, and with combining numbers and not atomic weights. First one must note his statement of the belief that ‘the entire chemical system consists of like progressions.’ To his mind the elements formed a system correlated and made up of progressions. This is, of course, not the ascending series of de Chancourtois and Newlands, but it seems to me a position much nearer to it than was reached by any chemist for more than half a century afterwards.

Again, in other portions of this volume Richter speaks of the necessity of deducing quality from quantity and vice versa. Thus he points out that the series of masses mentioned as forming arithmetical progressions are really series of affinities also, and the relative affinities might be deduced from the relative masses. Much space is also

given to the effort at tracing relationships of specific gravities. While it cannot be positively stated that Richter foresaw that important part of the periodic law that the properties of the elements are dependent upon the relative weights, he seems at least to have been possessed with the idea that what he called the masses of the elements had something to do with what he considered the qualities, or that they progressed similarly. And that they in the main progress similarly is about all we know with regard to them at the present day

I acknowledge that there is some difficulty in sifting out Richter's full meaning from the mass of mathematical calculation and one must be careful to avoid reading into his work the thought of later years. It is not strange that the tedium of following such involved calculations and speculations as his should have deterred his contemporaries from following his trend of thought or paying much attention to him. It cannot be claimed that he preceded Dalton in his conception of the Atomic Theory but Richter belongs to the number of the great original thinkers of chemistry and it is time that greater justice be done him.

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A REVIEW OF THE CHEMICAL CONSTITUTION OF
TOURMALINE AS INTERPRETED BY PENFIELD,
FOOTE AND CLARKE.

JOSEPH HYDE PRATT.

During the past ten years there have appeared three articles relating to the chemical composition of tourmaline; one on the Chemical Composition of Tourmaline by Prof. S. I. Penfield and H. W. Foote of Yale University, another by Prof. F. W. Clarke of Washington, on the Chemical Constitution of Tourmaline, and a third by Prof. G. Tschermak on "Über das Mischungsgesetz der Tourmaline." The views presented in these three papers all differ from each other and the latter two lead to very complicated formulae for tourmaline.

The paper by Prof. Penfield and Dr. Foote which was prior to the other two, takes up at length and in detail analyses of tourmaline from DeKalb, N. Y. and Hadden Neck,

Conn., giving method of selection and preparation of material, method of analysis and constitution of tourmaline. This paper also reviews very carefully the old analyses of tourmaline and in many cases shows the relation of these analyses to those that they had made. When it is considered that the two analyses referred to above on the DeKalb and Hadden Neck tourmaline, were made under the direction of the acknowledged foremost chemo-mineralogist of the world and who is known to be the most pains-taking and accurate in all chemical work he does, the conclusions that are deduced from these analyses made by him or under his direction, must have the greatest weight, even if they are to a certain extent antagonistic to results obtained from analyses made years before. The analyses of minerals which were made prior to 1870 were conducted under difficulties that have been very much lessened since that time. It is now possible to obtain pure material for analysis by the aid of heavy-solutions that are now at hand where formerly that analyzed was often acknowledged to be impure. Also in the advancement of Chemistry, new and improved methods have been devised by which it is now possible to make satisfactory and accurate determinations of various elements contained in the different minerals, where formerly great difficulty was experienced in determining certain of these and in some cases they were not determined at all.

It is observed that in many of the older mineral analyses no mention is made of the method of analysis or of the purity of the material analyzed and sometimes only an average of two or more analyses is given, so that those working at the present time on these or similar minerals have no way of making accurate comparisons between their results and those formerly obtained, and also there is no way of determining any error that might have been made in the old analyses.

Penfield and Foote give, as the result of their work, as the formula for tourmaline, $H_2B_2Si_4O_{21}$, or $H_{18}(B.OH)SiO_{19}$. In connection with the earlier analyses of tourmaline, they

have determined the oxygen ratios in thirty-three of these, from various localities of the world and in nearly all cases they approximate the formula derived by them and some instances it is very close to this. It must, however, be remembered that these earlier analyses were often made upon impure material and by methods that have been proved to be inaccurate. The formula they have deduced for tourmaline while it represents a complex boro-silic acid is a simple formula and one to which all tourmalines can be referred. That the tourmaline contains varying proportions of metals having different valences and of essentially different character, which replace the different hydrogens of the acids may seem peculiar, but while we cannot prove definitely regarding the molecular structure of minerals, still we can get some light on this subject from the various elaborate studies that have been made in organic chemistry. These have shown that one, two, three or more hydrogens can be replaced by simple metallic radicals or simple or compound organic radicals. If this is true in organic chemistry, it is just as true in inorganic chemistry and while as we said before, this cannot be proved conclusively as it can in organic chemistry still we have every right to believe that this is true and also to go a step further and make the statement that the different hydrogen atoms can be replaced by univalent, bivalent, or trivalent metals.

Prof. Clarke is taking for the formula of the tourmaline acid $H_{29}B_3Si_6O_{31}$. There are but few, however of the analyses that have been made of tourmaline, that correspond to this formula. In order to find formulae that will yield calculated percentage values that will agree with the different analyses, Clarke has introduced two formulae which he designates as $A = H_{29}B_3Si_6O_{31}$, $B = H_{31}B_3Si_6O_{33}$, and refers to the various tourmalines as being made up of different proportions of these two molecules. It will be seen that there is but little difficulty in making any of the tourmaline analyses correspond to formulae made up of combinations of these two molecules with different bases, but it leads to a molecule of

tourmaline that is made up of a great number of atoms, up to 3499, which has been calculated for a black tourmaline from Auburn, Maine. Prof. Clarke has given apparently as much weight to the older analyses as he has to the very recent ones. It will be found, however, that careful analytical work of the present time made by pains-taking analysts upon material that has been purified as far as possible and using analytical methods that are known to be accurate, that the formula deduced from these analyses will be found to be identical in most cases with the formula deduced from analyses made of the corresponding mineral from other localities. Also it is more reasonable to accept a simple formula than a more complete one, for it is a more natural supposition that the atoms are combining with each other in simple ratios to form the various mineral molecules, than in complex ratios.

Tschermak takes two formulae $\text{Si}_{12}\text{B}_6\text{Al}_{12}\text{Na}_4\text{H}_8\text{O}_{63} = (\text{Tu})$, and $\text{Si}_{12}\text{B}_6\text{Al}_{12}\text{Mg}_{12}\text{H}_8\text{O}_{63} = (\text{Tm})$, to which he refers all the tourmalines. Those formulae are derived from an acid $\text{H}_6\text{B}_6\text{Si}_{12}\text{O}_{63}$, which it will be seen is three times the formula $\text{H}_2\text{B}_2\text{Si}_4\text{O}_{21}$ which was deduced by Penfield and Foote. The question at once arises why Tschermak took the formula $\text{H}_6\text{B}_6\text{Si}_{12}\text{O}_{63}$ rather than one third this, the simpler one; and the one of Penfield and Foote. There is no argument in favor of this, Tschermak simply stating that this has been proved to be the acid formula for tourmaline. We can determine by substitution the formulae of many organic compounds whether they are the simpler formula or a multiple of it, but with our minerals this can not be determined and the simplest multiple of a formula has always been selected to represent the mineral. To carry out his theory Tschermak is obliged to take a third formula $\text{Si}_{12}\text{B}_6\text{Al}_6\text{Mg}_{22}\text{P}_2\text{O}_{64} = (\text{Tn})$ to make the composition of some of the tourmaline correspond to his proposed theory. He as well as Clarke has used all the old analyses, apparently considering them all accurate and unquestionable in the determination of the formulae advanced by them. Penfield on the other hand has derived from analyses that he knows to be accurate and to have been made upon the purest kind of

material; also he has investigated many of the older analyses, and proved conclusively in a number of cases that the material used was impure and that the methods employed would not give accurate results. Tschermak and Clarke are carrying their idea of the existence of mica molecules into the discussion of the constitution of tourmaline and try to make the analyses of tourmaline correspond to this same idea. There is, however, no tangible reason why one should suppose there is any relation between mica and tourmaline. Muscovite has been found pseudomorph after many minerals, some of which, as corundum, have no relation whatever to it.

Prof. Penfield in a later article, A Criticism on the Constitution of the Tourmaline, discusses the reasons advanced for his formula for tourmaline, and points out certain fallacies that are apparent in Prof. Clark's and Prof. Tschermak's discussions for the acceptance of their respective formulae. It has been generally conceded that one or more analyses of a mineral made at the present time by accurate workers under the most favorable circumstances are of much more value and infinitely more reliable in determining the chemical constitution or formula of the mineral, than *all* the earlier analyses. Also instead of taking some formula approximately derived from these earlier analyses and attempting to make the recent and known to be accurate analyses correspond to it, how much more reasonable is it to accept the formula derived directly from these recent analyses and to show how the earlier ones correspond to it closely in practically all cases, and sometimes identical with it.

Since Penfield's formula is the simplest, and is derived directly from recent analyses and is one to which all tourmalines can unquestionably be referred while those of Clarke and Tschermak are more complex and in most cases require a pair and sometimes three formulae in order to make the various tourmalines correspond to them, is not the weight of the argument in favor of the acceptance of the Penfield-Foote formula in preference to either of the latter ones?

SOME EAST AMERICAN SPECIES OF CRATAEGUS.

CONTRIBUTIONS FROM MY HERBARIUM, NO. XI.

W. W. ASHE.

CRATAEGUS RAVIDA. A small tree, 3-5m. in height, with short horizontal branches forming an oblong or oval crown, and dark brown scaly bark on the slender trunk; or sometimes a large shrub. Twig of the season stout, glabrous, red-brown becoming dull gray the second year, marked with a few pale round or oblong lenticels, armed with numerous stout 4-5cm. long dark purlish or blackish thorns; winter-buds ovate or subglobose, bright red-brown. Leaves glabrous, thick and firm, blades broadly ovate or nearly orbicular in outline, 4-6 cm. long, 3.5-5.5cm. wide, obtuse or subacute at the apex, rounded or broadly cuneate at the serrulate base, coarsely and doubly glandular serrate with 2-3 pairs of shallow irregular notches, 3-4 pairs of prominent deeply impressed primary veins which usually fork at or above the middle; petiole stout, 1.5-2cm. long, deeply grooved above, roughened with several pairs of red-brown glands, winged at the apex by the decurrent blade. Inflorescence a simple glabrous several-flowered cyme; calyx narrowly obconic, large, the short entire or serrulate lobes broadly triangular; stamens 10, large; styles 3-5, usually 4. The fruit, in simple 2-4 fruited clusters, on spreading glabrous pedicels, 1-2cm. long, is subglobose, somewhat thicker than long, 14-21mm. long, 16-24mm. thick, full and rounded at the apex, concave at base, russet, or olive mottled with orange, or orange-red, or sometimes yellow, capped by the short erect or spreading calyx lobes, their margins involute; flesh thick orange-yellow, firm and juicy, barely sweetish; seed 3-5, gener-

ally 4, large and coarse, 7-10mm. long, deeply grooved or nearly smooth on the broad rounded back, nearly central in the fruit; the cavity cylindrous, about 4mm. wide, very deep. The fruit falls soon after the foliage, late in October or in November, with the short, stout pedicels attached. In Washington County, Tennessee where this plant was observed, especially around Clarkson, it is uncommon. It grows in sunny rocky woods or on roadsides, often associated with the cock-spur thorn.

CRATAEGUS SCHUETTEI. A spreading much branched shrub 2-3m. in height. Twig of the season slender, glabrous, nearly straight, bright brown, becoming dull gray in the second year, armed with slender 4-6cm. long brown-purple thorns. Leaves thin but firm, glabrous beneath, pubescent when young on the upper surface especially on the midrib with short appressed hairs, soon becoming glabrous; the blades ovate or broadly ovate in outline, 3-6cm. long, 2.5-5cm. wide, acute at the apex, rounded or obtuse at base, very sharply and doubly glandular serrate except at the very base, with 3-5 pairs of sharp but short regular lateral lobes, 4-5 pairs of prominent veins; petiole slender, 1.7-2.5cm. long, very deeply grooved above. Inflorescence, a generally simple several-flowered cyme, 3-5cm. wide, the glabrous erect pedicels 1-2cm. long; styles 3-5, usually 4; stamens 20, large and erect; calyx hemispherical, broad and shallow, the lobes narrowly triangular or lanceolate, finely serrate, appressed pubescent, reflexed after anthesis. The fruit, borne in several-fruited clusters, or solitary, on erect or ascending pedicels 1-2 cm. long, in subglobose, or globular-pyriform, nearly 1.3cm. long and about as thick, dark red, sometimes capped by the appressed calyx-lobes when mature; seed generally 4 or 5, about 6 cm. long, somewhat ridged on the narrow back.

Green Bay, Wisconsin, where collected by Mr. J. H. Schuette, with whose name I associate the species. While closely related to *Crataegus latispala*, it can be separated from it by having narrower serrate pubescent calyx-lobes, which are reflexed after anthesis, and thinner, more sharply serrate leaves, shorter pedicels, and smaller seed.

CRATAEGUS DEPRESSA. A small tree or large bush with spreading or ascending branches, and dark gray rough bark on the trunk, that on the branches being smooth and light gray; twig of the season glabrous, lustrous brown, sometimes sparingly glaucous when young, marked with numerous pale lenticels, becoming light gray the second year, armed with a few dark purple-brown thorns; buds subglobose, bright red-brown. Leaves thick, firm, glabrous, very dark green above, much paler beneath, the blades broadly ovate, or nearly orbicular on vigorous shoots, 6-9cm. long, 4-7cm. wide, rounded or subcordate at the base, abruptly acuminate at the apex, coarsely, often doubly serrate nearly to the base with acuminate gland-tipped teeth, slightly and irregularly notched; petiole slender, 2-3cm. long, finely channelled above, roughened with a few inconspicuous glands, narrowly winged at the apex by the decurrent blade. Inflorescence a few-flowered glabrous simple cyme; the bractlets few, inconspicuous and early deciduous; pedicels 1.5-2.5 cm. long, spreading in fruit; calyx cup-shaped, broad, glabrous without, pilose within at the base, the lobes short, broad, soon deciduous; styles 4-5; stamens 10, early deciduous. Fruit depressed-globose, 12-14mm. broad, 6-12mm. long, borne in clusters of 2-4 or solitary, dark red, sparingly glaucous, the cavity broad and shallow, pilose within; seed 4-5, 6-7mm. long, the lateral faces smooth, the dorsal with a deep median groove.

Crataegus depressa belongs to a group of which *C. lacumacarpa* is the type, and most closely resembles that species, though easily separated from it by having larger and differently shaped leaves. Northern Missouri, where collected by me in 1899. I also refer here, No. 226; B. F. Bush, Dodson, Mo., July, 1899.

CRATAEGUS GRANDIS. A small tree 4-6m. in height, with dark gray scaly bark on the trunk, and long horizontal or ascending branches forming an oval or flat-topped crown; twigs glabrous, slender, those of the season light brown or russet, marked with few small inconspicuous lenticels, becoming bright gray the second year, sparingly armed with slender 4-6cm. long thorns; buds ovate, bright brown. Leaves thick and firm, dark green and shining above paler beneath, at first slightly pubescent above, especially on the midrib, soon glabrous, 5-6 pairs of prominent impressed parallel veins; the blades obovate or spatulate in outline, rounded, obtuse or abruptly acute at the apex, cuneate at the entire base, 3-5 cm. long, 2.5-3cm. wide, finely but sharply doubly serrate, seldom notched; petiole .5-2cm. long winged by the decurrent blade. Inflorescent a many-flowered glabrous corymb, sometimes minutely pubescent, especially on the calyx lobes; flowers 12-14mm. wide; calyx narrowly obconic, the entire or sparingly serrulate lobes very narrow, reflexed after anthesis; stamens normally 20, small and slender, anthers small purplish; styles, 2-3 usually 2. The fruit, borne in compound wide-spreading clusters on spreading or pendant pedicels, is globular, 11-14mm. thick bright crimson, sometimes sparingly pruinose, marked with few inconspicuous lenticels, often capped by the persistent spreading or erect, calyx-lobes; the cavity

broad and deep; seed 2-3, more or less prominently ridged on the back, 6-8mm. long.

Illinoi : collected by me along the Wabash river, July, 1899; C. F. Johnson: Freeport; J. H. Ferriss: near Chicago.

Crataegus grandis is related to *C. punctata* from which it is separated by having a more glabrous inflorescence, smaller calyx, smaller and more lustrous foliage, and globular bright red fruit.

CRATAEGUS ALBEMARLENSIS. A small tree 3-7m. in height with rather smooth dark gray bark on the trunk, and horizontal or ascending branches forming an oval crown; twig of the season glabrous, chestnut-brown, marked with numerous small pale lenticels, becoming steel-gray the second year, armed with few 4-5cm.-long thorns, or unarmed. Leaves glabrous, thin but firm, dark green above, much paler beneath; the blades ovate or broadly ovate in outline, 3-5cm. long, 2.5-4cm. wide, rounded or truncate at the base, acute at the apex, finely and sharply doubly serrate nearly to the base, generally with several pairs of irregular but shallow notches, with 3-5 pairs of very slender primary veins, petioles very slender, 1.5-3cm. long, finely grooved on the upper surface. Inflorescence a nearly simple glabrous few-flowered cyme 3-4cm. wide, the very slender pedicels 1.5-2cm. long, the slender glandular bractlets very early deciduous; stamens normally 10, stout; styles 4-5; calyx broad and shallow, glabrous without, villous within at the base, the lobes narrowly triangular, entire. Fruit globose or somewhat oblong, 9-12mm. thick, dark red when ripe, capped by the erect connivent calyx-lobes; the cavity small and narrow; seed 4-5, small, 5-6mm. long.

Crataegus Albemarlensis is not uncommon on the moist lands bordering swamps and streams in Hyde and Pam-

lico counties, North Carolina, where it is found growing in the shade of oaks and gums or along the roadsides.

Crataegus Holmesiana VILLIPES. This differs from the type in the stouter, and longer pedicels which are more or less villous. The petioles are often pubescent also. Eastern Pennsylvania and New York.

CRATAEGUS FERRISSI. A large shrub or generally a small tree 4-7m. in height with ascending or spreading branches forming an oblong or oval crown, the bark on the trunk dark gray and roughened, that on the branches smooth and light gray. Twigs rather stout, glabrous, sometimes sparingly glaucous, those of the season dull brown or purplish, becoming light gray the second year, armed with rather few short 2-3cm.-long thorns. Leaves dark green above, much paler beneath, thick and firm, the blades ovate in outline, 4-6cm. long, 2-5cm. wide, acuminate at the apex, rounded, truncate or subcordate at the base, with 3-4 pairs of prominent acuminate lobes, the points of the lower pair reflexed, the sinuses acute at base, finely and acuminately glandular serrate nearly to the base; petioles slender, terete, sometimes roughened with a few small glands, 1.5-2cm. long, sometimes slightly winged at the apex, purple at base; buds ovate, brown or red-brown. Inflorescence a many-flowered corymb; calyx obconic, the narrow triangular lobes glandular serrulate; stamens 20, small; styles 4-5, usually 5. The fruit, borne in several-fruited mostly compound pendant clusters, is glabrous, crimson, oblong or pyriform, 1-1.6 cm. long, .8-1.3cm. thick, and after ripening in October persists on the trees until after the leaves have fallen; flesh thick, yellow, sweet and mealy; seed 4-5, sometimes ridged on the back, 5-7mm. long; cavity obconic, 4-5mm. broad, about as deep, the persistent calyx-tube projecting beyond the fruit, the lobes deciduous or appressed.

Northern Illinois: J. H. Ferriss; W. C. Egan.

CRATAEGUS BICOLOR. A small tree with spreading or ascending gray branches forming an oblong crown, and dark gray nearly black bark on the thorny trunk. Twigs glabrous, slender, chestnut-brown when young, armed with slender, 4-5cm.-long thorns. Leaves thin but firm, glabrous dark green above, paler beneath, the blades ovate or nearly orbicular in outline, 4-7cm. long, 3-6cm. wide, sharply but finely glandular, usually doubly serrate nearly to the base, generally with 2-3 pairs of shallow notches, acute at apex, acute or truncate at base, 3-5 pairs of principal veins; petiole 1.5-3cm. long, slender, channelled above, narrowly winged for half its length by the decurrent blade, roughened on the upper surface by several glands. Inflorescence a several-flowered compound glabrous cyme, 3-4cm. wide, the branches 1-3cm. long; calyx broad and short, glabrous, the serrate triangular lobes rising from a broad base; stamens 20; styles 4-5. The fruit, on strict or spreading .8-1.8cm.-long pedicels, disposed singly or generally simple clusters of 2-4, is subglobose, generally slightly oblong 11-13mm. long, green or greenish mottled with red; calyx lobes generally sessile on the mature fruit, their base only persistent; flesh firm, white; cavity broad, very shallow, obconic; seed 4-5, small, 5-6mm. long, deeply grooved on the back, apical in the fruit.

Crataegus bicolor is found abundantly in sunny oak woods, especially on well-drained southern slopes, in the vicinity of Micaville and Spruce Pine, Mitchell County, North Carolina. It is frequently associated with *C. cruenta* which it resembles in habit and foliage, and from which it is separated by having more numerous seed and greenish fruit.

CRATAEGUS ATRO-PURPUREA. A small tree 4-7m. in height with dark gray or blackish scaly bark on the

trunk, and long spreading or ascending branches forming an oval crown. Twig of the season glabrous, chestnut-brown, becoming gray the second year, sparingly armed with 4-5cm-long thorns. Leaves glabrous, thin but firm, dark green and shining above, somewhat paler beneath, blades ovate or deltoid in outline, or on vigorous shoots nearly orbicular, 4-7cm. long, 3-7cm. wide, acute or obtuse at the apex, obtuse or truncate at the base, sharply doubly serrate, the teeth gland-tipped, sometimes with 2-4 pairs of very shallow notches, usually 4 pairs of primary veins; petiole slender, 2-3cm. long, grooved on the upper surface, winged at the apex by the decurrent blade. Inflorescence cymose, glabrous, sparingly glaucous, few-flowered, 3-5cm. wide, bractlets few, early deciduous; pedicels ascending, 1-2cm. long; calyx glabrous, short and broad, the lobes narrowly triangular; stamens 20, small; styles 3 exceptionally 4. The fruit, ripening late in October or in November after the leaves have fallen, and long persistent, in clusters of 2-5 on strict .7-2cm.-long pedicels, is oblong, 1-1.5cm.-long, 8-11mm. thick, rounded at the ends, dark red or purplish, scantily glaucous, capped by the nearly sessile persistent reflexed calyx-lobes; cavity obconic, broad and shallow; seed generally 3, somewhat apical in the fruit, 6-8mm. long, white, with shallow grooves on the rounded back, somewhat attenuate at the base; flesh firm, white, sweet. The foliage turns a dull yellow or brown and falls soon after the first severe frost.

Crataegus atro-purpurea frequents fields, roadsides and dry sunny woods in Yancy county, North Carolina, at an elevation of about 800m., but is not common.

It belongs to a group of which *C. macrosperma* and *C. haemacarpa* can be regarded as the types. From the former it is separated by the different outline of the

foliage, smaller fruit and fewer and smaller seeds; from the latter by having an oblong fruit with white flesh and fewer seed.

CRATAEGUS CARNOSA. A small bushy tree or a shrub with numerous ascending branches from near the base. Twigs glabrous, chestnut-brown, rather thick, straight or somewhat flexuous, armed with very numerous 4-6cm.-long thorns. Leaves glabrous, membranaceous, the blades ovate or elliptic in outline, 4-6cm. long, 2-4cm. wide, obtuse or acuminate at the apex, obtuse or acute at base, sharply serrate, 3-5 pairs of lobes from near the base, with 4-5 pairs of ascending primary veins; petiole 1.5-3cm. long, grooved on upper surface, narrowly winged for half its length or more by the decurrent blade. Inflorescence a glabrous several-flowered compound cyme, 3-4cm. wide; pedicels very short .8-1.5cm. long, erect; stamens 20, small; styles 2-3; calyx small, glabrous, the triangular lobes usually entire. Fruiting pedicels solitary or in clusturs, sometimes compound, of 2-5, spreading or ascending, .8-1.4cm. long. Fruit globose-pyriform, flattened at the apex, concave at base, generally broader than long, 1.2-2cm. broad, 1-1.8cm long, bright orange-red when ripe in October and persistent for sometime after the fall of the foliage (in 1899 persistent until late in December); flesh orange-yellow, thick and juicy; the sessile, reflexed calyx-lobes often persistent; cavity obconic, shallow; seed 2, exceptionally 3 or 4, deeply gooved on the back, 9-7mm. long. The leaves turn a dull yellow or brown and fall early, after the first severe frost.

I have seen *Crataegus carnosa* only in Yancey county, North Carolina, where it grows on roadsides and in sunny upland woods, often associated with *C. atro-purpurea* but is by no means common. It is easily seperated from

the other 20-stamened species of this region by its very narrow, sharply lobed leaves.

CRATAEGUS PRISMATICA. A small tree 3-5m. in height, or sometimes a large shrub, with short spreading branches forming a small oval or flattened crown, and dark, nearly black scaly bark on the trunk. Twigs of the season slender, flexuous or nearly straight, red-brown, becoming gray the second year, glabrous, armed with few 4-5cm.-long thorns. The glabrous, rather pale green leaves are thin but firm in texture, the blades elliptic, ovate, obovate or even spatulate in outline, 3-4.5 cm. long, 1.5-4cm. wide, rounded or obtuse at apex, rounded or cuneate at the serrate base, sharply glandular serrate, doubly serrate above the middle or with 1-3 pairs of shallow notches, 3-4 pairs of impressed primary veins; petiole 1.5-2cm. long, slender, channelled above, winged at the apex by the decurrent blade, roughened by 2-3 pairs of stalked glands; winter-buds globose, bright red-brown. The inflorescence is a nearly simple, glabrous few-flowered cyme, the short pedicels bracteate with 2-3 lanceolate glandular-margined bracts; calyx glabrous, the tube short and broad; stamens small, generally 10; styles 3, seldom 4; fruiting clusters 1-4-fruited, the bright red erect pedicels 1-1.5cm long, about the length of the fruit. Fruit globular-pyriform, somewhat thicker than long, 12-15mm. thick, 11-15mm. long, 3-angled in cross section, bright red; calyx-lobes lanceolate, sharply glandular-serrate above the middle, on the mature fruit slightly stalked, reflexed, bright red; the broad shallow cavity obconic; flesh firm, yellow, mealy; seed usually 3, seldom 4, apical in the fruit, about 6mm. long, 3-4mm. thick laterally, deeply dorsally grooved. The fruit falls with or soon after the fall of the foliage, late in October or the first half of November. The

foliage becomes bright red, mottled with orange and yellow early in October and is tardily deciduous after the first heavy frost.

Crataegus prismatica resemble in habit and foliage *C. flavo-carnis* from which it can be separated by having smaller and more obtuse leaves, pyriform fruit, fewer styles and seed. Banks of streams Madison county, North Carolina, especially along the French Broad river.

CRATAEGUS CRUENTA. A slender tree 5-7m. high with short ascending or spreading branches forming an oval or oblong crown, and dark gray or blackish rough bark on the trunk. Twigs of the season glabrous, slender, light brown, becoming steel-gray the second year, armed with very slender 2-4cm.-long chestnut-brown or purplish thorns. Leaves thin, bright green, glabrous, the blades broadly ovate, deltoid or nearly round in outline, 3-5cm. long, 2.6-5cm. wide, obtuse rounded or truncate at the entire base, acute at the apex, sharply and finely doubly serrate, with 2-3 pairs of shallow notches, 3-4 pairs of primary veins; petiole slender, 1.5-2.5cm. long, nearly terete, on vigorous shoots roughened with glands. Inflorescence a few-flowered compound cyme 5-6cm. wide, glabrous, somewhat glaucous; calyx glabrous, the tube broad and short, the entire triangular lobes rising from a broad base, reflexed after anthesis; stamens 20, small; styles generally 3. The fruit, solitary or in clusters of 2-4, on strict slender pedicels .8-1.8cm. long, is globose or somewhat attenuate at base, 9-13mm. long, about as thick, bright red, sparingly glaucous, capped by the short-stalked generally persistent reflexed calyx-lobes; flesh yellowish white, rather thin, firm, sweet; seed usually 3, generally slightly grooved on the rounded back, 6-7mm. long. The foliage, which is long persistent ac-

quires after frost many shades of yellow, red and purple and falls before the fruit which often persists until late in winter.

Crataegus cruenta is frequent in Yancey county, North Carolina, between Spruce Pine and Miraville, growing in sunny upland woods beneath oaks and hickories. It can be separated from the other 20-stamened forms of this region with which it is associated, by its smaller and broader leaves, and the small, bright red, usually 3-seeded fruit.

CRATAEGUS TRISPERMA. A tree 5-8m. in height with ascending or spreading branches forming an oblong crown, and a slender trunk with dark gray nearly black bark, armed with few thorns. Twig of season slender, glabrous, bright brown, becoming dull gray the second year, marked with pale lenticels, straight or nearly so, armed with few slender 4-5cm.-long thorns. Leaves glabrous, thin, bright green above, somewhat paler beneath, the blades ovate or broadly ovate in outline, 4-7cm. long, 3.5-6cm. wide obtuse or truncate at the base, acute or obtuse at the apex, sharply and coarsely doubly serrate, with 3-4 pairs of shallow lobes; petiole 1.5-2.5cm. long, grooved above, margined at the apex by the decurrent blade, roughened with several pairs of red glands, purplish at base. The inflorescence is a glabrous, generally simple cyme, 3-5cm. wide; pedicels .6-2cm. long; calyx obconic, the short broadly triangular lobes entire; styles 3-4, generally 3; stamens small, 10. The fruit, on erect or spreading .6-2cm. long pedicels, usually in clusters of 3-5, is globose, 10-13mm. thick, bright yellow or orange when ripe in October, capped by the short, sessile calyx-lobes; flesh rather thick and firm, white or pale yellow; seed generally 3, nearly central in the fruit, 5-7mm. long, deeply grooved on the rounded back. The leaves turn a

dull yellow or brown and fall soon after frost, before the fruit which is largely persistent until December.

The species above proposed is abundant in Yancey County, North Carolina, between the North and South forks of Toe river, at an elevation of about 800m, growing on roadsides and on sunny wooded slopes. It is separated from the other 10-stamened species with which it is associated by its globular fruit. It is most closely related to *C. riparia* of the Little Tennessee river basin, which differs from it in having larger fruit, more numerous nutlets, and a differently shaped leaf.

CRATAEGUS CRASSA. A small tree 4-6m. in height with slender bright red-brown twigs armed with numerous slender 3-4cm.-long thorns. Leaves dark green, thick and firm, pubescent above along the midrib, pubescent beneath when young, at length nearly glabrous, except for small tufts of hairs in the axils of the primary veins, obovate or nearly orbicular, obtuse or rounded at the apex, rounded or abruptly contracted at the entire base, glandular crenate or serrate, sometimes doubly so, with 1-3 pairs of shallow obtuse notches above the middle, 2-3 pairs of prominent ascending deeply impressed primary veins; petiole 1-2cm. long, slender, nearly terete pubescent above, broadly winged at the apex. Inflorescence a compound many-flowered cyme 4-5cm. wide; flowers about 1.5cm. wide, on slender erect glabrate pedicels; calyx small, about 3mm. long, pubescent, as well as the narrowly triangular acute glandular serrate lobes; styles 4-5; stamens 20, persistent; fruit oblong, 9-12mm. long, dark red, capped by the nearly sessile persistent calyx-lobes; flesh thin, sweet; seed usually 5, 4-5mm. long, smooth on the back and sides; cavity nearly 5mm. wide.

Eastern Pennsylvania. *C. crassa* belongs to the *flava* group. It is separated from *C. flava*, however, by its smaller fruit, which is not pyriform, and its more numer-

ous flowers.

Crataegus deltoides. A straggling shrub, or occasionally a small tree, with spreading sparingly armed branches, and slender glossy brown twigs which do not become gray until the third year. Leaves thick, firm, glabrous, dark green above, much paler beneath, deltoid or nearly orbicular in outline, 3-5cm. in diameter, truncate or subcordate at the base, sharply doubly glandular serrate, with several pairs of shallow notches, 3-5 pairs of prominent divergent lateral veins; petiole 1.5-2cm. long, nearly terete, glaucous. Inflorescence a 3-6-flowered nearly simple cyme, 3-5cm. wide; pedicels stout, erect, glabrous, glaucous; flowers 15-17mm. wide; calyx cup shaped, very broad, the very prominent oblong or ligulate lobes glabrous, serrate or entire, erect or spreading soon after anthesis; stamens normally 10; styles 3-4; fruit large, 15-17mm. thick, globular or somewhat depressed, concave at the base, dark red, sparingly pruinose; seed 3-4, ridged on the back, the lateral faces plane; cavity 6-7mm. wide.

Crataegus deltoides is frequent in southeastern Pennsylvania, and the adjoining parts of Maryland. It is related to *C. pruinosa* from which it is separated by its larger fruit and foliage, and fewer stamens.

CRATAEGUS PORRACEA. A tree 5-7m. high with spreading or ascending branches, forming an oval or rounded crown. Twig of the season glabrous, red-brown, becoming gray the second year, armed with short 2-3cm.-long thorns. Inflorescence a small, 3-4mm.-wide glabrous corymb, 6-10-flowered; flowers 15-17mm. wide; calyx obconic, the lobes narrowly triangular, entire or nearly so, reflexed after anthesis, generally deciduous before autumn; stamens 10; styles 3-5; fruit oblong, 10-13mm. long, dark red, sparingly glaucous; seed 3-5, furrowed on the back, the lateral faces plane; fruiting pedicel ascending or spreading .8-15cm. long; fruit persistent

after the leaves have fallen. Leaves thin, glabrous, bright green above, somewhat paler beneath, the blades small, 3-4.5cm. long, ovate, acute at apex, rounded or truncate at base, very finely and sharply doubly serrate all around, 4-5 pairs of sharp lateral lobes, the tips of the lower usually reflexed, 4-6 pairs of straight parallel veins; petiole slender, nearly terete, 1-1.8cm. long.

The species above proposed is related to *C. tenuifolia* from which it is separated by the smaller foliage and smaller fruit and corymbs. Northeastern Pennsylvania and the adjacent part of New York. The type material was collected by C. F. Saunders, near Susquehanna, Pa.

CRATAEGUS ALBICANS. A large shrub or a small tree, 4-7m. in height with spreading or ascending branches. Twig of the season glabrous, bright red-brown, sparingly glaucous, at length dull gray, armed with few 3-5cm.-long thorns. Leaves glabrous below, rough above, at least when young, with scattered very short hairs, especially along the midrib, firm in texture, the blades ovate in outline, 5-8cm. long, rounded or truncate at base, acute at apex, sharply and finely doubly serrate, with 4-6 pairs of shallow acute lobes; petiole slender, terete or nearly so, 2-3cm. long. Inflorescence a nearly simple cyme, 5-6cm. wide, 5-10; flowered, glabrous except the calyx-lobes; flowers about 17mm. wide; stamens normally 10; styles 4-5; fruit globular, 1-1.3cm. thick, dark red, glaucous, capped by the nearly sessile, spreading calyx-lobes, which are broadly triangular, usually entire, and pubescent on the upper surface; seed 4-5, 5-6mm. long, grooved on the back, the lateral faces plane; flesh thick, firm, yellowish, very sweet. The tips of the calyx-lobes often break off and the edges of the persistent base become involute,

Crataegus albicans has been collected in eastern Michigan by Mr. O. A. Farwell. It is related to *C. pruinosa*. Issued July 1, 1901. N. C. Nat. Hist. Survey.

A PECULIAR IRON OF SUPPOSED METEORIC ORIGIN, FROM DAVIDSON COUNTY, NORTH CAROLINA.

JOSEPH HYDE PRATT.

The iron to be described was found six or seven years ago by Mr. W. R. Harris on a hill-side that rises just east of the Lexington-Troy road about half a mile south of Cid P. O., Davidson County, N. C.

The iron originally weighed 13 lbs. 14 ozs., and its shape was somewhat oblong, 9 inches long by $6\frac{1}{2}$ inches in its widest part, and 2 inches thick in the center, but becoming much thinner than this around its outer edge. Surrounding the iron is a more or less oxidized surface which in some places extends into the iron for a quarter to nearly half an inch. Its surface is more or less pitted and it has very evidently lain in the earth for some time.

The iron has been cut and polished and the surfaces tested by etching but they showed neither the Widmannstatten figures nor the Neumann lines. Mr. Tassin of the United States National Museum who has also experimented with this iron states that "the etched surface presents a granular or stippled appearance overlaid with a network of fine lines. These lines are apparently without orientation and are so numerous as to give the iron a decidedly fibrous appearance." He also states that the "fractured surface shows traces of what is apparently an octahedral cleavage." This etched surface is dissimilar to the other so-called structureless meteorites that have been tested in the National Museum except the Scriba iron* which was found at Scriba, Oswego County, New York, in 1895, whose etched surface is very similar. This dissimilarity is of course against the meteoric nature of this iron as these tests are the unquestionable ones for a meteoric iron, but at the same time some irons that are known meteorites have not given them.

*Am. J. Sci. Vol. XL, 1841, p. 366.

In comparing the etched surface of this iron with those of a series of wood burned, coke and bloomery irons, Mr. Tassin, who has made a great many etching tests on irons of this sort, states that it is radically different in appearance from any of these manufactured irons that he has tested. Of course it must be taken into consideration that these manufactured irons that were tested were for the most part manufactured by established methods and for special purposes. What the effect of etching would be on a polished surface of some of the old charcoal irons which have been obtained by crude processes is not known. That a mass of cast iron of this weight and shape should have been carried and left in this section which is 15 to 29 miles from any railroad and 50 or a 100 miles from any known furnace is rather improbable.

This iron has been examined by a number men who are thoroughly familiar with all kinds of manufactured irons and they state that it is entirely different from any iron that they have ever seen. Mr. Kerr, a foundryman of Durham, North Carolina, who cut off a piece of this iron, stated that it was unlike any that he had ever seen and did not cut like any iron known to him. It is tough and a piece can only be chipped off of the main mass with difficulty; and it is not brittle like cast iron, but on the contrary is somewhat malleable.

There is considerable free carbon in the iron which is very apparent on a fresh fracture, and it leaves a black stain on any thing touching it. This interferes to some extent with the etching and partly explains the stippled appearance of the etched surface.

In its chemical composition it is different from the majority of the meteoric irons in having a small amount of nickel and containing some free carbon. Material was obtained for analysis from the interior of the iron where it showed no alteration, the turnings from this portion of the iron having been carefully selected at the time the iron was cut. It has been analyzed by Dr. Baskerville,* who used the method of analysis described below.

*University of North Carolina.

METHOD OF ANALYSIS.

A weighed portion of the iron turnings were treated with aqua regia, and brought to a syrup by direct heat, the nitric acid being driven off by addition of concentrated hydrochloric acid and evaporating several times to dryness on the water bath. The silica was finally rendered insoluble by heating at 110°C until all hydrochloric acid fumes were removed. It was then treated with dilute hydrochloric acid and boiling water and filtered. The filtrate was made up to 500 c. c. and reserved for further use. The precipitate after thorough washing was burned in a platinum crucible. After decarbonization it was fused with five parts sodium carbonate and one part potassium nitrate, taken up in dilute hydrochloric acid, evaporated to dryness and heated at 110°C . as above to render silica insoluble. The residue was then treated with hydrochloric acid and hot water, filtered and washed. The filtrate was made up to 250 c. c.

The precipitate was burned and the silica driven off by hydrofluoric acid. The residue was tested for titanium according to method of Weller* as modified by Hillebrand† and Dunnington,‡ after fusion with potassium disulphate, but none was detected.

The filtrates were tested for sulphur and phosphorus according to the ordinary methods of testing for the oxidized compounds of those elements, but not a trace of either was observed.

An aliquot part of the first filtrate (500 c. c.) was precipitated with ammonium hydroxide, filtered, and the precipitate washed, burned and weighed as Fe_2O_3 . The iron in another portion was precipitated as before, and then re-dissolved in dilute sulphuric acid, passed through a granulated zinc column reductor and titrated with standard potassium permanganate solution. This method gave the same results as were obtained by the gravimetric, thus showing the absence of alum-

*Ber. D. Chem. Ges. 15,2592

†J. Am. Chem. Soc. 17, 718.

‡J. Anal. and Appl. Chem. 5, 39.

inum. As the ammoniacal filtrate possessed no blue color, copper was reported absent.

The second filtrate (250 c. c.) was similarly treated and the iron combined with carbon and silicon determined which amounted to 1.81 per cent, this with the metallic iron gave the total iron present. After calculating the silicon (0.62 per cent) as iron silicide FeSi , that amount of iron (0.62 per cent) was taken from 1.81 per cent and the difference (1.17 per cent) was regarded as iron combined with carbon. This was subsequently checked as noted below.

Manganese was determined from an aliquot part of the two filtrates by the basic acetate method and long boiling of filtrate with an excess of bromine. The precipitate was burned and weighed as Mn_2O_4 .

Nickel and cobalt were separated from the filtrates which had been thoroughly oxidized and changed to chlorides by repeatedly extracting the ferric chloride by means of pure ether in a Rothe's pipette*. The Nickel and cobalt chlorides were then separated according to Blair† viz: by precipitation of the cobalt as the potassium cobaltinitrite, $\text{K}_3\text{Co}(\text{NO})_6$.

For total carbon two grams were dissolved in the double potassium and copper chloride. The undissolved graphite and carbide were caught on asbestos in a platinum Gooch crucible, dried and weighed.‡ The total carbon was determined by combustion in the Shimer§ apparatus.

The difference in the weight of the carbon found and the total undissolved residue was 1.17 per cent, which is the same as the combined iron not reported as combined with the silicon. (see above).

Every effort was made to determine the combined carbon, but the material was not attacked by nitric acid, even after digestion at 100°C . for twelve hours. The colorimetric method failed entirely.

*Mitt. a. den König. Teh. Vers. zu Berlin. 1892, part iii-Blair, 3rd. edit. p. 315.

†Ibid. p. 185.

‡Blair. *ibid.* p. 162.

§J. Am. Chem. Soc. 21, p. 557.

No effort was made to determine occluded gases.

The results of the analysis are given below:

| | | | |
|-----------------|---|----------------------------|-------|
| Iron 93.89 | { | Iron, metallic..... | 92.10 |
| | | Iron combined with carbon | 1.17 |
| | | Iron combined with silicon | .62 |
| | | Manganese..... | 92 |
| | | Nickel..... | 30 |
| | | Cobalt..... | 34 |
| | | Sulphur..... | None |
| | | Phosphorus..... | None |
| | | Aluminum..... | None |
| | | Titanium..... | None |
| | | Silicon..... | 62 |
| | | Carbon..... | 3.88 |
| | | Copper..... | None |

99.95

The above results show the iron to be considerably different in its chemical composition from the manufactured irons and, while the percentage of nickel is low, that does not preclude it from the meteorites. The presence of the nickel even in this small amount and of the cobalt with the total absence of sulphur, phosphorus, titanium and aluminum are strong factors against its being a manufactured iron and for its meteoric origin.

The Scriba iron already referred to, which is similar in structure to this iron, is decidedly different in its chemical composition. An analysis of this by Prof. Charles U. Shepard in 1841 gives the following results:

| | |
|----------|--------|
| Iron | 99.68 |
| Silicon | 0.20 |
| Aluminum | Trace. |

Total 99.88

This analysis, except as showing the iron to be a very pure one, does not add any weight to its meteoric character but the rather isolated country in which it was

found and its peculiar configuratoin have led to the belief that it is of meteoric origin although this is questioned by many.

The analysis, however, of the iron from Davidson County supports its meteoric origin and then again, its structure, while being different from that of the other known meteorites, together with the more or less isolated region in which it was found makes it very probable that this iron is of meteoric origin.

From the locality where this iron was found, namely, in the vicinity of Cid P. O., Davidson County, North Carolina, the name proposed for it is the "Cid" iron.

N. C. Geological Survey.

A METHOD OF LAYING OUT GRADES FOR SEWERS BY AID OF THE TRANSIT.

WILLIAM CAIN.

The transit method, as I shall term it, of laying out sewer grades, presupposes the use of the level in determining the elevations, so that both transit and level are used as in the ordinary method. The peculiarity of this method consists in this, that ultimately the transit telescope is pointed along a line parallel to the grade of the invert of the sewer and from this line of sight, distances can be measured down to locate any point desired as explained below.

As this is a very practical subject, the successive steps to follow will be given by aid of a particular example.

In the figure, suppose the elevation of the grade of the invert at the Man Hole, Station 0, to be 476.90 and that 420 feet from Station 0, or at Station 4+20, the elevation of grade is 488.79, giving a rise of 2.83 feet in a hundred. This much

is obtained from the profile. Suppose the trench partially dug, the depth of cutting being approximately given from the profile and that at intervals, say of 40 (more or less), *boards* are placed across the ditch and firmly embedded in the earth. These boards may be 6 or 8 inches in depth and their sides must be as near vertical as the eye can place them.

The successive steps are then as follows:

(1) Place the transit on the center line of the trench a certain convenient distance back of Station 0, as 10 feet or some multiple of 10. The elevation of the grade of invert just under the transit, supposed in the figure 10 feet back of Station 0, is thus, $476.90 - 0.28 = 476.62$.

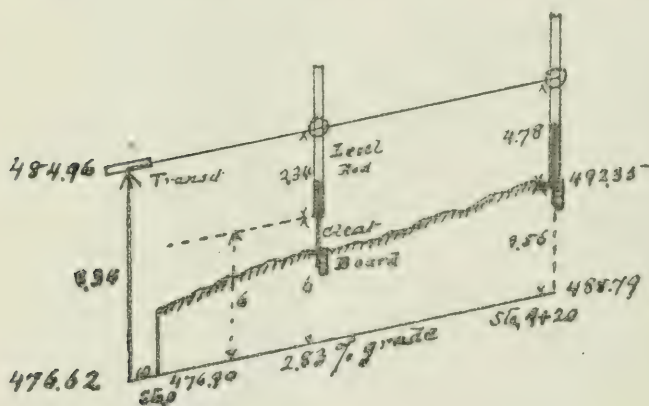
(2) With the transit sighted along the center line of trench set a rod or pencil on an edge of each "board," in line; mark the point with a pencil and then nail on a *cleat* to the board with a vertical edge on the point. After one nail is driven in cleat by aid of the vertical thread of the transit telescope, the top of the cleat is moved over until the edge is truly vertical. These cleats are say, 4 in. by 3/8 in. by 4 feet, though often longer cleats are needed.

If house connections are to be put in, the distance from board to board is measured with a steel tape and recorded, as the connections are generally located by the constructor with reference to the boards, numbered 1, 2, 3,

(3) The level is now set up, about midway of the length of trench considered and the elevation of the board at station $4+20$ is found, also the elevation of the telescope of the transit instrument. To find the last by the level, place the foot of the level rod on the ground and hold the rod against the transit axis and take the reading of the rod by the level and then compute the elevation of the foot of the rod. On adding to this, the height to axis of transit telescope as measured on the rod, we find the elevation of the transit axis (484.96 in figure). If the transit telescope has a level on it, it is best to bring the bubble to center, sight at a level rod held on a convenient bench mark and add the reading to the elevation of the bench to get the elevation of the transit axis.

(4) The difference between the elevations of the transit axis and that of the grade under it, is thus, $484.96 - 476.62 = 8.34$. The difference between the elevations of board and grade at station $4+20$ is, $492.35 - 488.79 = 3.56$. Therefore, set a target on the level rod at, $8.34 - 3.56 = 4.78$, hold on board at $4+20$ and bisect target with horizontal hair of transit telescope. The latter is now evidently sighted along a line parallel to grade, since the line of sight is 8.34 ft. above grade at transit and it is $3.56 + 4.78 = 8.34$ ft. above grade at station $4+20$.

Tack an envelope on the cleat at station $4+20$, with its top on the line of sight, for reference, and before each subsequent



observation, test the line of sight and correct if need be, by its aid. If the cleat is not long enough, nail on a strip to the board sufficiently long and tack the envelope on that.

(5) Suppose it desirable to drive nails in a certain number of cleats, 6 feet above grade; set the target on the level rod at $8.34 - 6 = 2.34$. Then let a common hand hold a hammer on the vertical edge of a cleat that is in the vertical plane containing the center line of the trench and rest the foot of the rod on it. The rodman then balances his rod carefully on the hammer head and moves it up or down, the hammer following,

until the transit man bisects the target. A pencil mark is then made across the hammer head and a nail driven horizontally into the edge of the cleat. The rod is held on it at once, and its position is altered if the target is not bisected. Points 6 feet above grade are similarly determined at other boards and eventually the constructor stretches a stout cord from nail to nail, to give him a continuous line, 6 ft. above grade, to work from. Similarly for 7 ft., 8 ft. . . lines, two nails being put in on a cleat where there is a change from one cord parallel to grade to another at a different distance from the invert.

(6) The line is now sufficiently checked by taking the elevations of the nails at station 0 and 4 + 20, by the level (which has not been moved). If these elevations are the assumed heights (6 ft., etc.) above the grades (476.90 and 488.79) at those stations, the work is correct.

The elevations have been given to hundredths in the above. They may be carried to thousands if preferred. It would seem that working to hundredths is sufficiently close unless the grade is very light. On steep grades errors of several hundredths in fact may be allowed, if there is nevertheless, a continuous fall in the sewer.

Man Holes are placed every few hundred feet, so that in case of obstruction, from any cause, including breaking of the sewer or pipe, the part of the line obstructed, can be quickly located by sighting through the pipe. The alignment both vertically and horizontally should be carefully done to afford a free sight. The method of locating the nails to string the cords on, outlined above is rapid in its working and does not take half the time required by the common method, which consists in getting by aid of the level, the elevations of each board, computing grades there, elevations of cords and thus heights from board to cord. These distances are then laid off on the cleats, which are then nailed on by aid of the transit, "in line." The rod reading on any nail should then be, height of instrument minus elevation of nail. Nine columns for computation are required in the field book and

the work is tedious, but it is systematic and little liable to mistake. In many cases, this method has to be used, especially in crossing a ridge. Where only two or three cleats have to be put in, this old method takes no more time than the transit method, but where a dozen cleats have to be set and the nails placed in them, the transit method, including all the preliminary work common to both methods, can be done in less than half the time.

By the latter method, it is seen from the profile, whether it is best to set the transit at the upper or lower end of the line, or perhaps the state of the filling in a completed trench, may determine the matter. Although station 0 was assumed above to be at a Man Hole, the reasoning and method is the same if it is anywhere on the line.

A possible source of error suggests itself by this method: does the transit telescope, as the object glass moves out or in, have its successive lines of sight (along the horizontal hair,) to lie in the same plane? This is doubted by some as the object glass is supposed to be placed mainly with reference to the vertical hair and all error of eccentricity of object glass, is said, by some makers*, of the transit, to be thrown into the horizontal hair.

The following test was made for the Fauth & Co. transit used in laying sewer grades at Chapel Hill, N. C.

Using 100 feet stations, pegs were put in at stations 0, 0+50. 1, 2, 3, 4, 5, 6 and their elevations found by running a line of levels from station 0 to 6, setting up the level, in turn, midway between two adjacent pegs and sighting on them, the true level was found as usual, so that the curvature of the earth was considered.

These elevations are given in column 2 of the following table.

*See *Engineering News* for May 23rd., 1901, page 377.

| Station | Elevations by level | Elevations by transit | Difference |
|---------|------------------------|--------------------------|------------|
| 0 | 10.000 | 10.000 | 0.000 |
| +50 | 9.204 | 9.205 | +0.001 |
| 1 | 8.742 | 8.739 | -0.003 |
| 2 | 7.960 | 7.961 | +0.001 |
| 3 | 6.229 | 6.225 | +0.005 |
| 4 | 6.125 | 6.121 | -0.004 |
| 5 | 7.809 | 7.808 | -0.001 |
| 6 | 9.712 | 9.712 | 0.000 |

Station 6 is thus found to be 0.288 ft. below station 0.

The *transit* was now set up at station 0 and the height of telescope axis above the peg at 0, found to be 4.955. The correction for curvature and refraction of earth being 0.007 for six hundred feet, a target was now set on the rod at, $0.288 + 4.955 + 0.007 = 5.250$ and the rod held at station 6.

The transit telescope was made next to bisect this fixed target, so that it was now sighted along a true horizontal line at station 0. The object glass alone was moved to get the rod readings on stations 5, 4, 3, . . . , in turn; but just before taking a sight, the fixed target at station 0 was sighted at, to correct any possible movement of the telescope. The correction for curvature was now subtracted from each reading in turn to get the elevations in column 3. The amount and character of the small errors in column 4, point rather to personal and instrumental errors than to any eccentricity of the object glass.

It is plain that this transit can be safely used for ordinary levelling or in establishing grades by "the transit method". Any transit can be similarly tested.

I have heard this transit method spoken of as a possibility, thirty years ago for railroad grades, but never knew it put in practice. It is very expeditious, taking only half the time of the level method.

THE CONE OF THE NORMALS AND AN ALLIED CONE FOR CENTRAL SURFACES OF THE SECOND DEGREE.*

ARCHIBALD HENDERSON, M.A.

1. The cone of the normals, which we shall designate throughout by C, will first be deduced for the ellipsoid given in its simplest form

$$\frac{x^2}{a^2} + \frac{y^2}{b^2} + \frac{z^2}{c^2} = 1 \dots\dots\dots (1)$$

The well known equation of the normal to the surface (1) at a point (f, g, h) is given by

$$\frac{x-f}{\frac{f}{a^2}} = \frac{y-g}{\frac{g}{b^2}} = \frac{z-h}{\frac{h}{c^2}} \dots\dots\dots (2)$$

2. From a point P, (x_0, y_0, z_0) , in space, six normals may in general be drawn to the ellipsoid.

If the normal

$$\frac{x-f}{\frac{f}{a^2}} = \frac{y-g}{\frac{g}{b^2}} = \frac{z-h}{\frac{h}{c^2}} = \lambda'$$

pass through the point P (x_0, y_0, z_0) , we have

$$\frac{x_0-f}{\frac{f}{a^2}} = \frac{y_0-g}{\frac{g}{b^2}} = \frac{z_0-h}{\frac{h}{c^2}} = \lambda \dots\dots\dots (1)$$

Then $x_0 - f = \frac{f\lambda}{a^2}, \quad \therefore f(a^2 + \lambda) = a^2 x_0, \quad \therefore f = \frac{a^2 x_0}{a^2 + \lambda}.$

*Dissertation presented to the Faculty of the University of North Carolina for the degree of Doctor of Philosophy, May 1901.

Similarly

$$g = \frac{b^2 y_0}{b^2 + \lambda}, \quad h = \frac{c^2 z_0}{c^2 + \lambda}. \quad \text{Since the point } (f, g, h)$$

is on the ellipsoid

$$\frac{a^2 x_0^2}{(a^2 + \lambda)^2} + \frac{b^2 y_0^2}{(b^2 + \lambda)^2} + \frac{c^2 z_0^2}{(c^2 + \lambda)^2} = 1.$$

This equation is of the sixth degree in λ and, since to every value of λ corresponds a particular normal, the number of normals from a given point to the ellipsoid is, in general, six.

3. The six normals from a point $P(x_0, y_0, z_0)$ to the ellipsoid lie on a cone of the second degree, with vertex at P .

The equations of the normal to the ellipsoid at the point (f, g, h) are

$$\frac{x-f}{a^2} = \frac{y-g}{b^2} = \frac{z-h}{c^2} = \lambda$$

Since this normal passes through the point $P(x_0, y_0, z_0)$ we have

$$\frac{x_0-f}{a^2} = \frac{y_0-g}{b^2} = \frac{z_0-h}{c^2} = \rho.$$

Next let us eliminate (f, g, h) . By subtraction we obtain

$$\frac{x-x_0}{a^2} = \lambda - \rho. \quad \text{Also since } \frac{x_0-f}{a^2} = \rho, \text{ it follows that } f = \frac{a^2 x_0}{a^2 + \rho};$$

$$\text{hence } x-x_0 = \frac{x_0}{a^2 + \rho}(\lambda - \rho). \quad \text{Then we have } a^2 + \rho = \frac{x_0}{x-x_0}(\lambda - \rho);$$

$$i. e., \quad \left(1 + \frac{x_0}{x-x_0}\right) \rho - \left(\frac{x_0}{x-x_0}\right) \lambda + a^2 = 0.$$

Similarly, $\left(1 + \frac{y_0}{y - y_0}\right) \rho - \left(\frac{y_0}{y - y_0}\right) \lambda + b^2 = 0$. And

$$\left(1 + \frac{z_0}{z - z_0}\right) \rho - \left(\frac{z_0}{z - z_0}\right) \lambda + c^2 = 0.$$

Eliminating ρ and λ between these last three equations, we have

$$\begin{vmatrix} 1 + \frac{x_0}{x - x_0}, & \frac{x_0}{x - x_0}, & a^2 \\ 1 + \frac{y_0}{y - y_0}, & \frac{y_0}{y - y_0}, & b^2 \\ 1 + \frac{z_0}{z - z_0}, & \frac{z_0}{z - z_0}, & c^2 \end{vmatrix} = 0.$$

Subtracting the second column from the first, we obtain

$$\begin{vmatrix} 1, & \frac{x_0}{x - x_0}, & a^2 \\ 1, & \frac{y_0}{y - y_0}, & b^2 \\ 1, & \frac{z_0}{z - z_0}, & c^2 \end{vmatrix} = 0. \quad - - - - (1)$$

Multiplying the first row by $\frac{x - x_0}{a^2}$, the second row by $\frac{y - y_0}{b^2}$,

the third row by $\frac{z - z_0}{c^2}$, we have

$$\begin{vmatrix} \frac{x-x_0}{a^2}, & \frac{x_0}{a^2}, & x-x_0 \\ \frac{y-y_0}{b^2}, & \frac{y_0}{b^2}, & y-y_0 \\ \frac{z-z_0}{c^2}, & \frac{z_0}{c^2}, & z-z_0 \end{vmatrix} = 0. \quad - - - \quad (2)$$

Adding the second column to the first and interchanging columns two and three, we obtain a third form:

$$\begin{vmatrix} \frac{x}{a^2}, & x-x_0, & \frac{x_0}{a^2} \\ \frac{y}{b^2}, & y-y_0, & \frac{y_0}{b^2} \\ \frac{z}{c^2}, & z-z_0, & \frac{z_0}{c^2} \end{vmatrix} = 0. \quad - - - \quad (3)$$

Transforming to parallel axes through the point $P(x_0, y_0, z_0)$ as origin by the substitution $x-x_0=x$, $y-y_0=y$, $z-z_0=z$ and employing form (1) above we obtain

$$\begin{vmatrix} 1, & \frac{x_0}{a^2}, & a^2 \\ 1, & \frac{y_0}{b^2}, & b^2 \\ 1, & \frac{z_0}{c^2}, & c^2 \end{vmatrix} = 0. \quad - - - \quad (4)$$

$$\text{or} \quad (b^2 - c^2) \frac{x_0}{x} + (c^2 - a^2) \frac{y_0}{y} + (a^2 - b^2) \frac{z_0}{z} = 0. \quad - \quad (5)$$

$$\text{or} \quad x_0(b^2 - c^2)yz + y_0(c^2 - a^2)zx + z_0(a^2 - b^2)xy = 0. \quad - \quad (6)$$

which is the equation of a cone of the second degree, having its vertex at the new origin, P.

4. The cone of the normals contains as generators the new axes, that is, the lines from P(x_0, y_0, z_0) parallel to the former axes.

To prove this we must note that the equation of a cone of the second degree referred to three of its generators as axes of coordinates is

$$fyz + gzx + hxy = 0. \quad - \quad - \quad - \quad (1)$$

by Example 4, p. 65 of C. Smith's Solid Geometry.

Since equation (6) of the preceding article is of the form (1), the theorem is proved.

5. The cone of the normals C contains as a generator the line from P(x_0, y_0, z_0) to O, the old origin,

The equations of the line OP are

$$\frac{x}{x_0} = \frac{y}{y_0} = \frac{z}{z_0} \quad - \quad - \quad - \quad - \quad (1)$$

This line OP lies on the cone given by equation (3) of Article 3, since equations (1) satisfy equation (3). It is plain that the origin is a point on the cone C.

6. It is a well known fact proved later on that the cone of the normals, vertex at P(x_0, y_0, z_0), contains the axes of the section obtained by drawing, through the point P, the plane conjugate to the diameter OP which passes through the point P. This fact has served as the point of departure for my succeeding investigations and has enabled me to deduce general formulas for the cone of the normals and also for an allied cone, for the most general central surfaces of the second degree.

7. *Lemma.* Find the equations for the axes of the section of the ellipsoid

$$\frac{x^2}{a^2} + \frac{y^2}{b^2} + \frac{z^2}{c^2} = 1. \quad - \quad - \quad - \quad (1)$$

made by the plane

$$lx + my + nz = 0. \quad - \quad - \quad - \quad (2)$$

Let (x, y, z) be the extremity of an axis. If the length of this axis be r , we must make $x^2 + y^2 + z^2 = r^2$ a maximum or a minimum, subject to the conditions (1) and (2) above.

Differentiating we have

$$x dx + y dy + z dz = 0. \quad - \quad - \quad - \quad (3)$$

$$\frac{x}{a^2} dx + \frac{y}{b^2} dy + \frac{z}{c^2} dz = 0. \quad - \quad - \quad - \quad (4)$$

$$l dx + m dy + n dz = 0. \quad - \quad - \quad - \quad (5)$$

Hence

$$\begin{vmatrix} x, & y, & z \\ \frac{x}{a^2}, & \frac{y}{b^2}, & \frac{z}{c^2} \\ l, & m, & n \end{vmatrix} = 0. \quad - \quad - \quad (6)$$

or

$$\frac{l}{b^2 c^2 x} (c^2 - b^2) + \frac{m}{c^2 a^2 y} (a^2 - c^2) + \frac{n}{a^2 b^2 z} (b^2 - a^2) = 0. \quad - \quad (7)$$

This is the equation of a cone having its vertex at the origin. The equations of the axes are then equations (2) and (7). The geometrical interpretation is that the axes are the intersections of the cone given by (7) with the plane given by equation (2).

8. To prove the cone of the normals C , vertex at $P(x_o, y_o, z_o)$, contains the axes of the section obtained by

drawing, through the point P, the plane conjugate to the diameter OP which passes through the point P.

It must be borne in mind that P is the center of the section. This is a well known fact and needs no proof in this thesis.

The plane through the point $P(x_o, y_o, z_o)$, having this point as the center of the section, is

$$lx + my + nz = p. \quad - \quad - \quad - \quad (1)$$

with the condition

$$lx_o + my_o + nz_o = p. \quad - \quad - \quad - \quad (2)$$

Also the diameter conjugate to plane (1), that is, passing through the origin and the point $P(x_o, y_o, z_o)$ the center of the section is

$$\frac{x}{a^2 l} = \frac{y}{b^2 m} = \frac{z}{c^2 n}. \quad - \quad - \quad - \quad (3)$$

Since (3) passes through $P(x_o, y_o, z_o)$, we have the conditions

$$\frac{x_o}{a^2 l} = \frac{y_o}{b^2 m} = \frac{z_o}{c^2 n}. \quad - \quad - \quad - \quad (4)$$

From equations (1) and (2) the plane through P may be written

$$l(x - x_o) + m(y - y_o) + n(z - z_o) = 0,$$

which becomes on employing the conditions (4)

$$\frac{xx_o}{a^2} + \frac{yy_o}{b^2} + \frac{zz_o}{c^2} = \frac{x_o^2}{a^2} + \frac{y_o^2}{b^2} + \frac{z_o^2}{c^2}. \quad - \quad (5)$$

If we take a plane parallel to plane (5), through the center of the ellipsoid, it will have for its equation

$$\frac{xx_o}{a^2} + \frac{yy_o}{b^2} + \frac{zz_o}{c^2} = 0. \quad - \quad - \quad - \quad (6)$$

The axes of the section of the ellipsoid by the plane (6) are given by the intersection of plane (6) with the cone

$$\begin{vmatrix} x, & y, & z \\ \frac{x}{a^2}, & \frac{y}{b^2}, & \frac{z}{c^2} \\ \frac{x_0}{a^2}, & \frac{y_0}{b^2}, & \frac{z_0}{c^2} \end{vmatrix} = 0. \quad - \quad - \quad (7)$$

from equation (6), Article 7, Lemma.

A cone parallel to this, having its vertex at the point $P(x_0, y_0, z_0)$ for origin, will have for its equation the equation (7). But the co-ordinates will be referred to the new axes through P, parallel to the former axes. Transferring back to the original axes by the transformation $x = x - x_0$, $y = y - y_0$, $z = z - z_0$, equation (7) becomes

$$\begin{vmatrix} x-x_0, & y-y_0, & z-z_0 \\ \frac{x-x_0}{a^2}, & \frac{y-y_0}{b^2}, & \frac{z-z_0}{c^2} \\ \frac{x_0}{a^2}, & \frac{y_0}{b^2}, & \frac{z_0}{c^2} \end{vmatrix} = 0.$$

or

$$\begin{vmatrix} x-x_0, & y-y_0, & z-z_0 \\ \frac{x}{a^2}, & \frac{y}{b^2}, & \frac{z}{c^2} \\ \frac{x_0}{a^2}, & \frac{y_0}{b^2}, & \frac{z_0}{c^2} \end{vmatrix} = 0, \quad - \quad - \quad (8)$$

which is the equation of the cone of the normals C by equation (3), Article 3.

The conclusion may be stated as follows:

All parallel sections of an ellipsoid are similar and similarly situated conics. The axes of plane (5) through P are parallel to the axes of plane (6) through the origin. The cones (7) and (8) are parallel. But the cone (7) contains the axes of the section of the ellipsoid by the plane (6). Hence the cone (8) contains the axes of the section of the ellipsoid by plane (5). But the cone (8) is the cone of the normals for the point P . Hence the cone of the normals C , vertex at P , contains the axes of the section obtained by drawing, through the point P , the plane conjugate to the diameter OP , which passes through the point P .

8. A very interesting conclusion follows from this. We have proved in Article 4 that the cone C contains a trirect-angular trihedral. If a cone contain one set of three generators mutually at right angles, it contains an infinity of such sets (C. Smith's Solid Geometry, §109.) Since the cone C contains the axes of the section through P (these axes are at right angles), it must also contain the normal through P to the plane of section.

10. By means of the facts so far known we are able to deduce the cone C in a very simple way.

The equation of C referred to axes through its vertex $P(x_0, y_0, z_0)$, parallel to the original axes, is of the form

$$fyz + gzx + hxy = 0.$$

since it contains the new axes as generators. Transforming to the original axes by the transformation $x = x - x_0$, $y = y - y_0$, $z = z - z_0$, this equation becomes

$$f(y - y_0)(z - z_0) + g(z - z_0)(x - x_0) + h(x - x_0)(y - y_0) = 0. \quad (1)$$

Also, since C passes through the origin, $x = y = z = 0$, and equation (1) becomes

$$\frac{f}{x_0} + \frac{g}{y_0} + \frac{h}{z_0} = 0. \quad - \quad - \quad - \quad (2)$$

Since finally it contains the normal

$$\frac{x - x_0}{\left(\frac{x_0}{a^2}\right)} = \frac{y - y_0}{\left(\frac{y_0}{b^2}\right)} = \frac{z - z_0}{\left(\frac{z_0}{c^2}\right)} \quad [\text{Art. 8, Eq. (5)}]$$

to the plane having $P(x_0, y_0, z_0)$ for its center,

$$f \frac{y_0 z_0}{b^2 c^2} + g \frac{z_0 x_0}{c^2 a^2} + h \frac{x_0 y_0}{a^2 b^2} = 0. \quad (3)$$

Eliminating f , g and h between (1), (2) and (3),

$$\begin{vmatrix} (y - y_0)(z - z_0) & (z - z_0)(x - x_0) & (x - x_0)(y - y_0) \\ \frac{1}{x_0} & \frac{1}{y_0} & \frac{1}{z_0} \\ \frac{y_0 z_0}{b^2 c^2} & \frac{z_0 x_0}{c^2 a^2} & \frac{x_0 y_0}{a^2 b^2} \end{vmatrix} = 0. \quad (4)$$

This equation, on multiplying the third row by $\frac{a^2 b^2 c^2}{x_0 y_0 z_0}$, and dividing the first row by the expression $(x - x_0)(y - y_0)(z - z_0)$, becomes

$$\begin{vmatrix} \frac{1}{x - z_0} & \frac{1}{y - y_0} & \frac{1}{z - z_0} \\ \frac{1}{x_0} & \frac{1}{y_0} & \frac{1}{z_0} \\ \frac{a^2}{x_0} & \frac{b^2}{y_0} & \frac{c^2}{z_0} \end{vmatrix} = 0. \quad (5)$$

or

$$\begin{vmatrix} x_0 & y_0 & z_0 \\ x-x_0 & y-y_0 & z-z_0 \\ 1 & 1 & 1 \\ a^2 & b^2 & c^2 \end{vmatrix} = 0. \quad (6)$$

on multiplying the first column by x , the second column by y , the third column by z . Equation (6) is the cone of the normals C [See equation (1), Article 3].

11. I shall next show that the cone of the normals C may be discovered from the equations concerned in finding the axes of the non-central section of an ellipsoid. I was led to this consideration by the fact that the cone C contains the axes of a non-central section, if its vertex is the center of the section.

The center of the section of the ellipsoid

$$\frac{x^2}{a^2} + \frac{y^2}{b^2} + \frac{z^2}{c^2} = 1$$

made by the plane

$$lx + my + nz = p \quad (1)$$

is given by the equations

$$\frac{x_0}{a^2 l} = \frac{y_0}{b^2 m} = \frac{z_0}{c^2 n} = \frac{p}{a^2 l^2 + b^2 m^2 + c^2 n^2} \quad (2)$$

where $P(x_0, y_0, z_0)$ is the center of the section. [See C. Smith's Solid Geometry, Ex. 2, pp. 43-4.] Now transforming the origin to $P(x_0, y_0, z_0)$, with axes through it parallel to the former, by the transformation $x = x + x_0$, $y = y + y_0$, $z = z + z_0$, we see that the equation of the ellipsoid becomes

$$\left(\frac{x^2}{a^2} + \frac{y^2}{b^2} + \frac{z^2}{c^2} \right) + 2 \left(\frac{xx_0}{a^2} + \frac{yy_0}{b^2} + \frac{zz_0}{c^2} \right) + \left(\frac{x_0^2}{a^2} + \frac{y_0^2}{b^2} + \frac{z_0^2}{c^2} - 1 \right) = 0$$

Equation (1) has become, by the transformation above and the condition $lx_0 + my_0 + nz_0 = p$,

$$lx + my + nz = 0.$$

Hence from equations (2),

$$\frac{xx_0}{a^2} + \frac{yy_0}{b^2} + \frac{zz_0}{c^2} = \frac{(lx + my + nz)p}{a^2l^2 + b^2m^2 + c^2n^2} = 0.$$

It follows that

$$\left. \begin{aligned} \frac{x^2}{a^2} + \frac{y^2}{b^2} + \frac{z^2}{c^2} + k &= 0 & (3) \\ lx + my + nz &= 0 & (4) \end{aligned} \right\}$$

are the equations of the section referred to the new axes, where

$$k = \frac{x_0^2}{a^2} + \frac{y_0^2}{b^2} + \frac{z_0^2}{c^2} - 1.$$

The cone with vertex $P(x_0, y_0, z_0)$ and passing through the intersection of the sphere

$$x^2 + y^2 + z^2 = r^2$$

and the ellipsoid

$$\frac{x^2}{a^2} + \frac{y^2}{b^2} + \frac{z^2}{c^2} + k = 0$$

is given by

$$\frac{x^2}{a^2r^2} (r^2 + ka^2) + \frac{y^2}{b^2r^2} (r^2 + kb^2) + \frac{z^2}{c^2r^2} (r^2 + kc^2) = 0. \quad (5)$$

[See C. Smith's Solid Geometry, Ex. 5, p. 55.]

Every semi-diameter of the surface, whose length is r , is a generating line of this cone. This cone will, for all values of

r , be cut by the plane (4) in two straight lines which lie along equal diameters of the section; and, when r is equal to *either* semi-axis of the section, these equal diameters will coincide. That is, the plane (4) will touch the cone (5) when r is equal to *either* semi-axes of the section of the ellipsoid by the plane. Hence, to find the equations of the axes, that is, the equations of the lines of contact, we must identify the plane (4) with the tangent plane to (5) at some point (x_1, y_1, z_1) . This tangent plane may be written

$$\frac{x x_1}{a^2 r^2} (r^2 + k a^2) + \frac{y y_1}{b^2 r^2} (r^2 + k b^2) + \frac{z z_1}{c^2 r^2} (r^2 + k c^2) = 0.$$

which, when compared with (4), gives the equations

$$\frac{\frac{x_1}{a^2 r^2} (r^2 + k a^2)}{l} = \frac{\frac{y_1}{b^2 r^2} (r^2 + k b^2)}{m} = \frac{\frac{z_1}{c^2 r^2} (r^2 + k c^2)}{n}$$

Putting each of these fractions equal to $-\lambda$, we have, on dropping accents,

$$\frac{x}{a^2} + x \frac{k}{r^2} + \lambda l = 0.$$

$$\frac{y}{b^2} + y \frac{k}{r^2} + \lambda m = 0.$$

$$\frac{z}{c^2} + z \frac{k}{r^2} + \lambda n = 0.$$

Eliminating $\frac{k}{r^2}$ and λ , we obtain

$$\begin{vmatrix} \frac{x}{a^2} & x & l \\ \frac{y}{b^2} & y & m \\ \frac{z}{c^2} & z & n \end{vmatrix} = 0.$$

Transforming to the original axes by the transformation $x = x - x_0$, $y = y - y_0$, $z = z - z_0$, we have

$$\begin{vmatrix} \frac{x - x_0}{a^2}, x - x_0, l \\ \frac{y - y_0}{b^2}, y - y_0, m \\ \frac{z - z_0}{c^2}, z - z_0, n \end{vmatrix} = 0.$$

which becomes on applying equations (2)

$$\begin{vmatrix} \frac{x - x_0}{a^2}, x - x_0, \frac{x_0}{a^2} \\ \frac{y - y_0}{b^2}, y - y_0, \frac{y_0}{b^2} \\ \frac{z - z_0}{c^2}, z - z_0, \frac{z_0}{c^2} \end{vmatrix} = 0.$$

which is the cone of the normals for the point $P(x_0, y_0, z_0)$ by equation (2), Article 3.

The geometrical interpretation is that the axes are obtained by the intersection of the cone of the normals for $P(x_o, y_o, z_o)$ with the plane

$$lx + my + nz = p.$$

12. To prove geometrically that the cone of the normals for P contains the line OP from P to the origin.

By Article 7, Lemma, the cone having its vertex at the origin, parallel to the cone of the normals, and containing the axes of the section of $lx + my + nz = 0$, and $\frac{x^2}{a^2} + \frac{y^2}{b^2} + \frac{z^2}{c^2} = 1$, is given by

$$\begin{vmatrix} x & y & z \\ \frac{x}{a^2} & \frac{y}{b^2} & \frac{z}{c^2} \\ l & m & n \end{vmatrix} = 0. \quad - \quad - \quad (1)$$

Since this cone is of the form

$$fyz + gzx + hxy = 0,$$

it contains as generators three conjugate diameters of the ellipsoid. [C. Smith's Solid Geometry, Ex. 5, p. 90.] Since the diameter conjugate to the plane $lx + my + nz = 0$ - (2) forms, with the axes of the section, three conjugate diameters, therefore the cone (1) contains the diameter conjugate to plane (2), that is the line OP .

Hence the cone of the normals for $P(x_o, y_o, z_o)$, parallel to and exactly like cone (1), having one point in common with a generator of (1) must contain that generator, which is OP (Compare Article 5).

13. I am seeking the general equation of the cone of the normals for central surfaces of the second degree, given in their most general form. Since the method of Article 11 is

perfectly general in its application, I shall apply it to the general equation of the second degree.

The general equation of the second degree having its center at the origin is

$$f(x, y, z) = ax^2 + by^2 + cz^2 + 2fyz + 2gzx + 2hxy + d' \\ = \phi(x, y, z) + d' = 0. \quad - \quad - \quad (1)$$

[See C. Smith's Solid Geometry, Article 75.]

Transform to parallel axes through the center $P(x_0, y_0, z_0)$ of the section of $f(x, y, z) = 0$ by the plane

$$lx + my + nz = p \quad - \quad - \quad - \quad (2)$$

by means of the transformation equations $x = x + x_0$, $y = y + y_0$, $z = z + z_0$.

We must note, however, that the center $P(x_0, y_0, z_0)$ of the section is given by

$$\frac{1}{l} \frac{\delta f}{\delta x_0} = \frac{1}{m} \frac{\delta f}{\delta y_0} = \frac{1}{n} \frac{\delta f}{\delta z_0} = -2\lambda \text{ say.} \quad - \quad (3)$$

[Compare C. Smith's Solid Geometry, Ex. 2, pages 43 and 44.] That is

$$\left. \begin{aligned} ax_0 + hy_0 + gz_0 + \lambda l &= 0, \\ hx_0 + by_0 + fz_0 + \lambda m &= 0, \\ gx_0 + fy_0 + cz_0 + \lambda n &= 0, \\ lx_0 + my_0 + nz_0 - p &= 0. \end{aligned} \right\} \quad - \quad - \quad (4)$$

By the transformation mentioned above $f(x, y, z) = 0$ becomes

$$\phi(x, y, z) + f(x_0, y_0, z_0) + 2axx_0 + 2byy_0 + 2czz_0 \\ + 2f(yz_0 + y_0z) + 2g(zx_0 + z_0x) + 2h(xy_0 + x_0y) = 0. \quad (5)$$

$$\text{or } \phi(x, y, z) + f(x_0, y_0, z_0) + 2x(ax_0 + hy_0 + gz_0) \\ + 2y(hx_0 + by_0 + fz_0) + 2z(gx_0 + fy_0 + cz_0) = 0. \quad (6)$$

On applying formulas (4), equation (6) becomes

$$\phi(x, y, z) + f(x_0, y_0, z_0) - 2\lambda(lx + my + nz) = 0. \quad (7)$$

But since $lx + my + nz = p$ and $lx_0 + my_0 + nz_0 = p$, where x, y, z are referred to old origin,

$$l(x - x_0) + m(y - y_0) + n(z - z_0) = 0$$

and since too $x = x + x_0, y = y + y_0, z = z + z_0$, we have

$$lx + my + nz = 0, \quad - \quad - \quad - \quad (8)$$

the equation of the plane through P (x_0, y_0, z_0), the new origin.

Hence, from (7),

$$\left. \begin{aligned} \phi(x, y, z) + k &= 0. \\ lx + my + nz &= 0. \end{aligned} \right\}$$

are the equations of the section, where

$$k = f(x_0, y_0, z_0).$$

The cone with vertex at P and passing through the intersection of the sphere

$$x^2 + y^2 + z^2 = r^2$$

and the surface

$$\phi(x, y, z) + k = 0$$

is given by

$$r^2 \phi(x, y, z) + k(x^2 + y^2 + z^2) = 0 \quad - \quad (9)$$

which is obtained by forming a homogeneous equation from these two equations.

Every semi-diameter of the surface, whose length is r , is a generating line of cone (9). This cone will, for all values of r , be cut by the plane $lx + my + nz = 0$ in two straight lines which lie along equal diameters of the section, and,

when r is equal to either semi-axis of the section, these equal diameters will coincide. That is, the plane $lx + my + nz = 0$ will touch the cone when r is equal to *either* semi-axis of the section of the surface by the plane. Hence, to find the equations of the axes, that is, the equations of the lines of contact, we must identify the plane $lx + my + nz = 0$ with the tangent plane to the cone at some point (x_1, y_1, z_1) . This tangent plane is

$$(r^2\phi'_{x_1} + 2kx_1)x + (r^2\phi'_{y_1} + 2ky_1)y + (r^2\phi'_{z_1} + 2kz_1)z = 0.$$

Hence

$$\frac{r^2\phi'_{x_1} + 2kx_1}{l} = \frac{r^2\phi'_{y_1} + 2ky_1}{m} = \frac{r^2\phi'_{z_1} + 2kz_1}{n}.$$

Then

$$\frac{\phi'_{x_1} + 2\frac{k}{r^2}x_1}{l} = \frac{\phi'_{y_1} + 2\frac{k}{r^2}y_1}{m} = \frac{\phi'_{z_1} + 2\frac{k}{r^2}z_1}{n} = 2\lambda' \text{ say.}$$

Clearing out and dropping accents,

$$\phi'_x + \frac{2k}{r^2}x - 2\lambda'l = 0$$

$$\phi'_y + \frac{2k}{r^2}y - 2\lambda'm = 0$$

$$\phi'_z + \frac{2k}{r^2}z - 2\lambda'n = 0$$

Hence

$$\begin{vmatrix} \phi'_x & x & l \\ \phi'_y & y & m \\ \phi'_z & z & n \end{vmatrix} = 0.$$

Transform back to the original axes by the substitution $x = x - x_0$, $y = y - y_0$, $z = z - z_0$, and note that

$$\begin{aligned}\phi'_{x-x_0} &= 2(ax + hy + gz)]_{x-x_0} \\ &= 2[(ax + hy + gz) - (ax_0 + hy_0 + gz_0)] \\ &= f'_x - f'_{x_0} = f'_x + 2\lambda l \text{ from equations (4).}\end{aligned}$$

We have then

$$\begin{vmatrix} \frac{\delta f}{\delta x} + 2\lambda l & x - x_0 & l \\ \frac{\delta f}{\delta y} + 2\lambda m & y - y_0 & m \\ \frac{\delta f}{\delta z} + 2\lambda n & z - z_0 & n \end{vmatrix} = 0.$$

or

$$\begin{vmatrix} \frac{\delta f}{\delta x} & x - x_0 & l \\ \frac{\delta f}{\delta y} & y - y_0 & m \\ \frac{\delta f}{\delta z} & z - z_0 & n \end{vmatrix} = 0. \quad - \quad (10)$$

which becomes by virtue of the equations

$$\frac{1}{l} \frac{\delta f}{\delta x} = \frac{1}{m} \frac{\delta f}{\delta y_0} = \frac{1}{n} \frac{\delta f}{\delta z_0}$$

$$\left| \begin{array}{cc} \frac{\delta f}{\delta x} & x - x_0 \\ \frac{\delta f}{\delta y} & y - y_0 \\ \frac{\delta f}{\delta z} & z - z_0 \end{array} \right| = 0. \quad (11)$$

The equation (11), by analogy with the result of Article 11, should prove to be the cone of the normals for the point P.

We shall now apply the tests, which are of the following nature:

I. It should contain the normal to the plane $lx + my + nz = p$, drawn through the point P(x_0, y_0, z_0).

II. It should pass through the origin.

III. It should be capable of containing three generators at right angles.

Since equation (10) is satisfied for

$$\frac{x - x_0}{l} = \frac{y - y_0}{m} = \frac{z - z_0}{n},$$

the equations of the normal to the plane

$$lx + my + nz = p$$

through the point P(x_0, y_0, z_0), condition I is satisfied.

Test II is verified since equation (11) is satisfied for $x = y = z = 0$.

Test III is verified since the cone (11) contains the normal, to the plane $lx + my + nz = p$, drawn through the point P(x_0, y_0, z_0) and also, by the method of derivation, contains the axes of the section of the conicoid by the plane $lx + my + nz = p$.

Hence equation (11) is the equation of the cone of the nor-

mals for the point $P(x_0, y_0, z_0)$ for the most general central surface of the second degree.

14. A second proof may be obtained as follows: The equations

$$\left. \begin{aligned} \phi(x, y, z) + k &= 0 \\ lx + my + nz &= 0 \end{aligned} \right\} \quad - \quad - \quad - \quad (1)$$

of the preceding article suffice to define the section whose axes we are seeking.

Let (x, y, z) be the co-ordinates of the extremity of an axis whose length is r .

Hence

$$x^2 + y^2 + z^2 = r^2$$

must be a maximum or a minimum, subject to the conditions (1).

Therefore

$$\phi'_x dx + \phi'_y dy + \phi'_z dz = 0$$

$$x dx + y dy + z dz = 0$$

$$l dx + m dy + n dz = 0$$

Hence

$$\begin{vmatrix} \phi'_x & \phi'_y & \phi'_z \\ x & y & z \\ l & m & n \end{vmatrix} = 0.$$

This is the same as equation deduced in Article 13. The remainder of the proof follows precisely as in Article 13.

15. Equation (11) when applied to the equation of the ellipsoid

$$\frac{x^2}{a^2} + \frac{y^2}{b^2} + \frac{z^2}{c^2} = 1$$

gives the result already found in Article 3, which is a further demonstration that it is the true equation desired. It may also be applied to the equation of the hyperboloid of one sheet

$$\frac{x^2}{a^2} + \frac{y^2}{b^2} - \frac{z^2}{c^2} = 1$$

and to the equation of the hyperboloid of two sheets

$$\frac{x^2}{a^2} - \frac{y^2}{b^2} - \frac{z^2}{c^2} = 1.$$

Equation (11), Article 13, is the equation of the cone of the normals for the following reasons: There are three central surfaces of the second degree—the ellipsoid and the hyperboloids of one and two sheets. The three tests applied in Article 13 are properties belonging to any central surface of the second degree, since the cone of the normals for the ellipsoid may be immediately transformed into the corresponding equations for the hyperboloids of one and two sheets by changing c^2 into $-c^2$, and b^2 into $-b^2$, c^2 into $-c^2$ respectively. Hence the properties proved for the ellipsoid hold also for the hyperboloids and hence for all central surfaces of the second degree.

16. The feet of the normals from a point $P(x_o, y_o, z_o)$ to the ellipsoid lie upon a cone of the second degree whose vertex is at the origin.

The equations of the normal to the ellipsoid at the point (f, g, h) are

$$\frac{x - f}{\left(\frac{f}{a^2}\right)} = \frac{y - g}{\left(\frac{g}{b^2}\right)} = \frac{z - h}{\left(\frac{h}{c^2}\right)} = \lambda \text{ say.}$$

Since this normal passes through the point $P(x_o, y_o, z_o)$, we have

$$\frac{x_0 - f}{\left(\frac{f}{a^2}\right)} = \frac{y_0 - g}{\left(\frac{g}{b^2}\right)} = \frac{z_0 - h}{\left(\frac{h}{c^2}\right)} = \lambda' \text{ say.}$$

$$\text{Hence } x_0 - f = \frac{f}{x} \lambda', \text{ or } a^2 + \lambda' = \frac{a^2 x_0}{f}.$$

Then

$$(a^2 + \lambda') = \frac{a^2 x_0}{x}, \quad (b^2 + \lambda') = \frac{b^2 y_0}{y}, \quad (c^2 + \lambda') = \frac{c^2 z_0}{z},$$

where (x, y, z) as *current co-ordinates* replace (f, g, h) .

Multiplying these equations respectively by $(b^2 - c^2)$, $(c^2 - a^2)$, $(a^2 - b^2)$ and adding we obtain

$$\frac{a^2 x_0 (b^2 - c^2)}{x} + \frac{b^2 y_0 (c^2 - a^2)}{y} + \frac{c^2 z_0 (a^2 - b^2)}{z} = 0. \quad (C')$$

This is the equation of a cone, vertex at the origin, and passing through the feet of the normals from $P(x_0, y_0, z_0)$ to the ellipsoid.

This cone passes through $P(x_0, y_0, z_0)$, since it is satisfied for $x = x_0$, $y = y_0$, $z = z_0$, and hence the line joining the origin to the point P is a generator of this cone.

The intersection of the two cones C and C' is composed:—

(i) of the straight line OP ,

(ii) of a twisted curve which we shall designate by the letter K .

The intersection of K with the ellipsoid gives the six points which are the feet of the six normals from the point $P(x_0, y_0, z_0)$ to the ellipsoid.

Since the cone C' is of the form

$$Ayz + Bzx + Cxy = 0$$

it contains three perpendicular generators. [This property

holds for any central surface of the second degree, since C' retains the same form when b^2 and c^2 are changed into $-b^2$ and $-c^2$.]

[Compare C. Smith's Solid Geometry, Article 109, p. 85.]

If it contains one set, it contains an infinity of such sets. A new method at once suggests itself for deducing the equation of cone C' . As my purpose has been to deduce the equation of the cone C' for the most general equation of a central surface of the second degree, I was foiled up to this point since the method of solution above given is not general in its application. The new method which I shall presently give is perfectly general in its application and has enabled me to deduce the equation of the cone C' for the most general equation of central surfaces of the second degree.

17. The line from the origin to the point P is the normal to the central plane

$$x_0x + y_0y + z_0z = 0. \quad - \quad - \quad - \quad (1)$$

Since the cone C' contains any set of three perpendicular generators, it contains the normal to the plane (1) and should contain the axes of the section of the ellipsoid by the plane (1). Now, by Article 7 above, the cone giving by its intersection with (1) the axes of the section is

$$\frac{x_0}{b^2c^2x} (c^2 - b^2) + \frac{y_0}{c^2a^2y} (a^2 - c^2) + \frac{z_0}{a^2b^2z} (b^2 - a^2) = 0,$$

passing through O and P , or

$$\frac{a^2x_0}{x} (b^2 - c^2) + \frac{b^2y_0}{y} (c^2 - a^2) + \frac{c^2z_0}{z} (a^2 - b^2) = 0,$$

which is the cone C' as found in Article 16.

I shall next apply this method to the general equation of the second degree having its center at the origin.

18. Find the equations for the axes of the section of the surface

$$f(x, y, z) = ax^2 + by^2 + cz^2 + 2fyz + 2gzx + 2hxy + d' = 0 \quad (1)$$

made by the plane

$$lx + my + nz = 0. \quad - \quad - \quad - \quad (2)$$

Let (x, y, z) be the co-ordinates of the extremity of an axis. If the length of this axis be r , we must make

$$x^2 + y^2 + z^2 = r^2$$

a maximum or a minimum, subject to the conditions (1) and (2).

Hence

$$\left. \begin{aligned} \frac{\delta f}{\delta x} dx + \frac{\delta f}{\delta y} dy + \frac{\delta f}{\delta z} dz &= 0 \\ x dx + y dy + z dz &= 0 \\ l dx + m dy + n dz &= 0 \end{aligned} \right\}$$

Then

$$\begin{vmatrix} \frac{\delta f}{\delta x} & \frac{\delta f}{\delta y} & \frac{\delta f}{\delta z} \\ x & y & z \\ l & m & n \end{vmatrix} = 0. \quad - \quad - \quad (3)$$

is the equation of the cone which gives by its intersection with $lx + my + nz = 0$ the equation of the axes of the section.

19. Find the equation of a cone whose vertex is at the origin and which passes through the feet of the normals from $P(x_0, y_0, z_0)$ to the surface

$$f(x, y, z) = ax^2 + by^2 + cz^2 + 2fyz + 2gzx + 2hxy + d' = 0. \quad (1)$$

We know by Article 17 that this cone determines by its in-

tersection with the plane through the origin perpendicular to OP .

$$x_0x + y_0y + z_0z = 0 \quad - \quad - \quad - \quad (2)$$

the axes of the section of (1) by (2).

By equation (3), Article 18, this cone has for its equation

$$\begin{vmatrix} \frac{\partial f}{\partial x} & \frac{\partial f}{\partial y} & \frac{\partial f}{\partial z} \\ x & y & z \\ x_0 & y_0 & z_0 \end{vmatrix} = 0. \quad - \quad - \quad (3)$$

Is this the required cone C' ? Two tests will now be applied. In order that equation (3) should represent the equation of Cone C' , it should contain as a generator the line OP . This is true, since equation (3) is satisfied for $x = x_0$, $y = y_0$, $z = z_0$.

It should also be capable of containing three generators at right angles.

Now the condition that a cone

$$ax^2 + by^2 + cz^2 + 2fyz + 2gzx + 2hxy = 0$$

shall contain three generators mutually at right angles is

$$a + b + c = 0. \quad - \quad - \quad - \quad (4)$$

[C. Smith's Solid Geometry, §109, page 85.]

Now the cone (3), when cleared out, becomes

$$(gy_0 - hz_0)x^2 + (hz_0 - fx_0)y^2 + (fx_0 - gy_0)z^2 + \dots = 0.$$

Applying condition (4) we have

$$(gy_0 - hz_0) + (hz_0 - fx_0) + (fx_0 - gy_0) = 0,$$

which is identically true.

A further verification of the truth of this result is made as follows:

The equation (3) when applied to the ellipsoid

$$\frac{x^2}{a^2} + \frac{y^2}{b^2} + \frac{z^2}{c^2} = 1$$

gives for the equation of C'

$$\begin{vmatrix} x & y & z \\ a^2 & b^2 & c^2 \\ x_0 & y_0 & z_0 \end{vmatrix} = 0$$

or

$$\begin{vmatrix} 1 & 1 & 1 \\ a^2 & b^2 & c^2 \\ 1 & 1 & 1 \\ x & y & z \\ x_0 & y_0 & z_0 \end{vmatrix} = 0$$

or

$$\frac{a^2 x_0}{x} (b^2 - c^2) + \frac{b^2 y_0}{y} (c^2 - a^2) + \frac{c^2 z_0}{z} (a^2 - b^2) = 0.$$

The last equation written is identical with equation (C') of Article 16, thus completing our verification of this equation (3).

In like manner the cone C' for the hyperboloid of one sheet

$$\frac{x^2}{a^2} - \frac{y^2}{b^2} - \frac{z^2}{c^2} = 1$$

may be written down

$$\begin{vmatrix} x & y & z \\ a^2 & b^2 & -c^2 \\ x_0 & y_0 & z_0 \end{vmatrix} = 0$$

or

$$\begin{vmatrix} 1 & 1 & 1 \\ \frac{1}{a^2} & \frac{1}{b^2} & -\frac{1}{c^2} \\ x_0 & y_0 & z_0 \\ x & y & z \end{vmatrix} = 0$$

or

$$\frac{a^2 x_0}{x} (b^2 + c^2) - \frac{b^2 y_0}{y} (c^2 + a^2) + \frac{c^2 z_0}{z} (b^2 - a^2) = 0.$$

Lastly, the cone C' for the hyperboloid of two sheets

$$\frac{x^2}{a^2} - \frac{y^2}{b^2} - \frac{z^2}{c^2} = 1$$

is given by the equation

$$\begin{vmatrix} x & y & z \\ \frac{x}{a^2} & -\frac{y}{b^2} & -\frac{z}{c^2} \\ x_0 & y_0 & z_0 \\ x & y & z \end{vmatrix} = 0$$

or

$$\begin{vmatrix} \frac{1}{a^2} & -\frac{1}{b^2} & -\frac{1}{c^2} \\ 1 & 1 & 1 \\ \frac{x_0}{x} & \frac{y_0}{y} & \frac{z_0}{z} \end{vmatrix} = 0$$

or

$$\frac{a^2 x_0}{x} (c^2 - b^2) + \frac{b^2 y_0}{y} (c^2 + a^2) - \frac{c^2 z_0}{z} (a^2 + b^2) = 0$$

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